LINSEED OIL

AND OTHER SEED OILS

AN INDUSTRIAL MANUAL

BY

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MEM. AM. SOC. M.E.

PROFESSOR OF MECHANICAL ENGINEERING IN THE POLYTECHNIC INSTITUTE OF BROOKLYN

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PREFACE

Few commodities enter less directly into consumption than linseed oil; yet fewer still find as wide a range of important applications. The seed-crushing industries are complex in their operative methods and commercial relations, rather than with respect to the machinery and equipment employed. These complications give opportunity for instructive study which is, in its outcome, suggestive to any manufacturer.

The first eight chapters deal with standard forms of equipment, with which crushers are generally thoroughly familiar. It is believed, however, that the descriptions and illustrations given form a collated body of information more readily available for use in this form than otherwise. They are unquestionably necessary to afford completeness to the review. American practice is throughout treated as standard, but constant reference is made to the widely diverging methods which prevail abroad, where the linseed-crushing industry is conducted on diametrically different principles.

Some apology may be necessary for the introduction of algebraic notations in Chapters II, V, IX, and X. The subjects discussed have been heretofore treated in a purely qualitative way and with little agreement as to practical policies. It is believed that the more quantitative general analysis here presented is better fitted for the development of operating standards.

There are extant many excellent manuals on oil analysis. It has seemed desirable, however, to incorporate with the text the chemical methods in general use for determining purity. These are to some extent available to the analytical chemist from other sources. The present work, with a good general text-book on quantitative analysis, should furnish a rather more condensed and convenient manual for the usual practitioner.

CONTENTS

CHAPTER I.

Introductory.

CHAPTER II.

The Handling of Seed and the Disposition of Its Impurities.

CHAPTER III.

Grinding.

CHAPTER IV.

Tempering the Ground Seed and Molding the Press Cake.

CONTENTS.

CHAPTER V.

Pressing and Trimming the Cakes.

CHAPTER VI.

Hydraulic Operative Equipment.

CHAPTER VII.

The Treatment of the Oil from the Press to the Consumer.

CHAPTER VIII.

Preparation of the Cake for the Market.

CHAPTER IX.

Oil Yield and Output.

CHAPTER X.

Shrinkage in Production.

CHAPTER XI.

Cost of Production.

CHAPTER XII.

Operation and Equipment of Typical Mills.

CHAPTER XIII.

Other Methods of Manufacturing.

CHAPTER XIV.

The Seed Crop.

CONTENTS.

CHAPTER XV.

The Seed Trade.

CHAPTER XVI.

Chemical Characteristics of Linseed Oil.

CHAPTER XVII.

Boiled Oil.

CHAPTER XVIII.

Refined and Special Oils.

BIBLIOGRAPHICAL NOTE

THE principal publications dealing with linseed oil have discussed the subject from the chemical standpoint. Such works as those of Livache,[1] Mulder,[2] Andes,[3] Hurst,[4] Wright,[5] Brannt,[6] and Lewkowitsch [7] illustrate the class of chemical manuals referred to, dealing with oil analysis, and particularly, in some cases, with drying oils. The only considerable collection of data on the operation of linseed oil mills is that contained in a book by John Bannon, entitled *Linseed Oil Manufacture and Treatment,* published in 1897.[8] Information more specifically along manufacturing lines is given in an excellent pamphlet by Spencer Kellogg, published in Buffalo, 1903. This is, however, very brief. Information of especial value, which has been of unusual service to the writer, is to be found in the pages of the trade papers, including *The Paint, Oil, and Drug Reporter* of New York, the *Paint Oil, and Drug Review* of Chicago, and several others. Official sources freely used in the present work include the *Rules of the New York Produce Exchange*, the *Rules of the New York Linseed Association*, the regulations of the *Minnesota Grain Commission,* of the *Chicago Board of Trade*, etc. The effort has been made to give due credit in the text to all other sources from which information has been drawn.

[1] *Varnishes, Oil Crushing, etc.;* Livache and McIntosh. London: Scott, Greenwood & Co.

[2] *Die Chemie der Austrocknenden Oele.*

[3] *Drying Oils, Boiled Oil and Dryers.* Scott, Greenwood & Co.

[4] *Dictionary of Chemicals.* Scott, Greenwood & Co.

[5] *Oil Analysis;* C. Alder Wright. H. C. Baird & Co.

[6] *Animal and Vegetable Fats and Oils.* H. C. Baird & Co.

[7] *Chemical Analysis of Oils, Fats, and Waxes.* London: Macmillan & Co.

[8] The National Provisioner Publishing Company, Chicago.

LIST OF ILLUSTRATIONS

LINSEED OIL AND OTHER SEED OILS

CHAPTER I.

INTRODUCTORY.

Development of the linseed-oil industry in the United States during the past half century.—Operation and equipment of early mills.—Migration and extension of the flax crop.—Improved machinery and commercial conditions.—Present production of linseed oil.—Receipt of seed at the mill.—Screening.—Treatment of screenings.—Grinding.—The heaters.—Object of heating the meal.—Molding.—Pressing.—Hydraulic systems.—Trimming.—Packing the cake.—Filtering.—The markets for seed, oil, and cake.—Effect of freights on cost of operation.—Desirable locations for linseed-oil mills.—Some leading crushers.—The cotton-seed industry.—A typical modern linseed-oil mill.—The largest mill in the world.

UNTIL about 1850, the cultivation of flax in the United States was practiced chiefly with a view to the utilization of the fiber. The seed was a waste product, or at best a by-product. During the past fifty years this condition has been wholly changed. The fiber is now almost universally wasted, the seed having become the sole object of cultivation. From it are produced linseed oil and linseed cake.

From a very early date, oil has been extracted from the seed of the flax by means of hand screw presses. These were superseded early in the last century by horizontal hydraulic presses, which, in turn, were displaced by vertical hydraulic presses, patented by Edwin Hills about 1850. The seed was handled entirely by manual labor. It was first fed to a pair of horizontal cast-iron rolls which gave it a preliminary crushing, then shoveled to the "muller" stones, described in Chapter III. The seed was finely crushed between the mullers and the bed stone, being meanwhile kept thoroughly wet. After reaching the proper condition of fineness and moisture, the meal was "cooked" in steam-heated kettles, and then placed in woolen bags, which were laid in an envelope of woven hair and subjected to the action of the press. The

hard cakes left after the expression of the oil weighed eight or nine pounds each, and the usual type of press held from six to eight cakes. About sixty pounds of cake were therefore turned out at each pressing, against an average of probably 200 pounds at the present day. The cakes contained up to 15 per cent of oil.

Up to the time of the war of secession, the national output of linseed oil did not exceed 1,000,000 gallons per year, there being imported, in order to supply the demand for oil, about 6,000,000 gallons additional, in oil or in its seed equivalent. From about 1865, the cultivation of flaxseed moved westward from Ohio into the virgin soils of the prairie states. Flax was found to be a good "first" crop on new land, and its production increased enormously. Meanwhile, improved industrial conditions stimulated the demand for linseed oil and its products. In ten years the flax crop quadrupled, yet the seed was practically all crushed, and the products marketed, west of the Alleghenies. The East was still obliged to depend for its requirements upon imports of seed or oil, the former coming usually from India.

Shortly after 1870, the old-fashioned muller stones were discarded in favor of the present type of chilled-iron rolls, arranged vertically one above another in "stands" four or five rolls high. These produced fine, dry meal from the whole seed. At the same time, the present method of cooking the meal in steam kettles, imparting the necessary moisture by means of either steam or water introduced into the kettle, was successfully inaugurated. Concurrent improvements were made in commercial conditions affecting the industry. Prior to 1880, flaxseed had been shipped in bags, usually furnished by the oil manufacturer to the farmer. Seed for sowing was also supplied, contracts being made for the resulting crops. By 1885, these practices were discontinued, the oil mills buying their raw material in the open market. Ship-

to satisfy special local demands for oil from imported seed. Practically no linseed oil is exported from the United States, and very little is imported, the duty being 20 cents per gallon. The domestic consumption of oil seldom exceeds 60,000,000 gallons annually, requiring about 24,000,000 bushels of seed. The average production of seed from 1898 to 1903 was about 24,000,000 bushels, resulting in a considerable surplus necessarily exported or carried over from year to year. The increased production during the past four years has been concurrent with a similar, though not an equal, increase in consumption.

At the present day, although some important modifications in the usual mode of treatment are being introduced, linseed oil is commonly expressed from the seeds of the flax plant by means of the hydraulic press. The process, as exemplified in the United States, involves the following operations: The seed is usually received either from boats or from cars. If from boats, the usual form of marine "leg" employed in grain elevators is lowered through the various hatches, successively, the seed being thus carried up the leg by means of a bucket elevator, and discharged through scales to a belt conveyor which distributes it to the storage tanks. As the grain is cleaned down, the labor of "trimmers" becomes necessary to shovel the seed toward the elevator boot, the final cleaning up of the boat's hold being accomplished by sweeping the seed into bags. Shipments by rail are dumped from the side of the car into a chute, spilling being avoided by joints of bagging. This discharges into a pit in which is located the boot of a stationary bucket elevator. The trimming of the cars is done by a wide shovel, guided by hand but operated by power.

The seed having been weighed and delivered to the storage tanks is taken out as needed by stationary elevator legs fed at first by gravity and finally by means of the power shovel. These elevators discharge to belt or screw conveyors which carry the seed to the sifters. The last are oscillating screens, intended to take out only the coarser particles such as grains of corn and wheat, and sometimes bits of metal, nails, etc. Such screenings are collected and discarded. The finer impurities carried in the seed are not removed by this method of screening. When seed is received by direct shipment from the grower, as is frequently the case at some of the western oil mills, the percentage of fine impurities is usually very large. Special treatment then becomes necessary. Usually, the impurities are removed from the seed before crushing the

latter, in order to avoid impairing the quality of the oil. The screenings are then sometimes separately crushed, producing a small quantity of inferior oil, and a soft cake which can be used only as an adulterant for oil meal. Sometimes the screenings are mixed directly with the oil meal, but this is more likely to impair the quality of the meal than the former procedure. Sometimes they, or the cakes from them, are mixed with ground flaxseed; occasionally they can be sold as screenings at a fair price.

From the sifters a third system of elevators and conveyors carries the seed to the working bins over the rolls. Screw conveyors running under the working bins distribute the seed to the feed boxes of the various roll "stands," and the seed drops in a thin stream to the fluted top roll, which spreads it across the entire width of the face of the rolls. Usually one stand of rolls is provided for each three presses. The stands are five rolls high, and as the seed passes between each two rolls it receives four successive crushings, being subjected to the greatest pressure, and consequently most finely ground, during its last transit. The chilled-iron rolls reduce the seed to fine meal, which is conveyed to the heaters or kettles.

When cold-pressed oil is produced, the heater is not used. Very little cold-pressed oil is made at the present time. Ordinarily, one heater is installed to serve from five to seven presses. In the heaters, the meal is subjected to heat, moisture, and agitation. The temperature is usually raised to about 180 degrees, the meal meanwhile being thoroughly stirred and mixed. Proper treatment in the heaters increases the yield of oil from the seed. The introduction of moisture into the meal breaks up the oil cells from the sedimentary particles, and is known to facilitate expression. As little moisture should be used as possible, however, since wet meal has a detrimental influence on press cloths and on the quality of the cake. All moisture imparted in the kettles must eventually be evaporated from either the oil or the cake. It is therefore considered good practice to introduce as little moisture as possible, and in fact, excepting with very old, dry seed, some mills inject no moisture whatever.

After the meal has been properly cooked or "tempered," it is drawn out in fixed quantities of about 20 pounds at a time to the molding machine or former. In this, it is subjected to moderate hydraulic or steam pressure, or sometimes to the direct application of power, forming a compact cake, wrapped in a blanket of camel's hair, known as the

"press cloth." The operation of the oil mill, up to the conclusion of the tempering, is continuous, and nearly automatic. With the molding of the cake, manual labor comes in. One former is used with each heater. As the cakes are formed, they are carried to, and placed in, the press. This is usually constructed to hold from 16 to 24 cakes, one lying on top of another with iron plates interposed. If the cake is to be branded, the brand is produced by a die worked in the plate. Ordinarily, in this country, the plates are padded on each side with wire and hair mats, which are less severe on the expensive press cloth than a bare iron plate. Sometimes, however, bare plates are used, with corrugations to prevent the press cloths from slipping out. Every precaution is taken to keep the meal hot while in the press, in order to keep up the yield of oil.

The presses are each provided with a ram, usually about 16 inches in diameter, which travels from below upward, from a strong cylinder in which the desired hydraulic pressure is maintained. Two pressures and two complete hydraulic systems are usually employed, one operating at from 400 to 800 pounds per square inch, the other at from 2800 to 4000 pounds. The lower pressure is first applied. This rapidly compresses the cakes and finally causes the oil to start flowing; at which point, either by hand or automatically, the press cylinder is disconnected from the low-pressure system and connected to the high-pressure line. This more intense pressure expresses the greater part of the oil from the cakes. It is continued for several minutes. The oil drains from the plates (slightly inclined toward the rear) to galvanized iron gutters, which carry it to a down spout on the back of the press. The spout discharges into wood boxes or troughs, which carry the oil to the tanks, the incline and arrangement of troughs being such as to afford a considerable time for the settlement of suspended matter from the slowly moving current of oil. After the cakes have been in the press for from 30 to 60 minutes, the ram is lowered and the cakes removed. These are now as hard as boards, and the press cloth adheres to them firmly. This is removed, or "stripped," and the cakes trimmed, either by hand or by machine, to remove the soft edges, which contain a relatively high percentage of oil. The "trimmings" are ground to meal and returned to the heaters to be re-pressed along with fresh meal. Where the cakes are required to be of exact dimensions (which is rarely the case) the necessary size is obtained by adjustments in the trimming.

The trimmed cakes are packed, by hand or mechanically, in bags holding from 275 to 375 pounds each, and are then ready for weighing and export shipment. American stock-raisers are prejudiced against the feeding of linseed cake, and practically all of it is exported, excepting such as may be ground up into oil meal, for which there is a limited domestic demand.

The "raw" oil from the press-room tank, after settling for some hours, is pumped to the filter presses, where it slowly percolates through canvas cloths, depositing much of the sediment which it contains. After a more or less protracted period of storage in tanks, it is ready for the market. A considerable portion of the oil is in most mills subjected to special supplementary treatments, which will be described later, to fit it for use in certain specific applications, as for varnish making, the manufacture of oilcloth, etc.

Certain natural and commercial conditions underlie and affect the entire organization of the linseed industry. The bulk of the flaxseed is obtained from Minnesota and Dakota, the primary markets being, for lake shipments, Duluth, and for rail shipments, Minneapolis. An inferior grade of seed is grown in Kansas and Nebraska, for which market is found at Kansas City or Chicago. Chicago receives seed from both territories, usually by rail from the northern district. The "western" mills, by which are meant mills located at or west of Chicago, form a class distinct from those in the East. Generally they pay less for their seed, and receive a less pure seed. Their operation is apt to be rather less economical. As an ordinary rule, they grind their output of cake. Their markets for oils are less diversified, and they consequently produce larger proportions of ordinary raw oils. The Minnesota and Dakota seed is known as "Northwestern"; that from Kansas and Nebraska as "Southwestern." Eastern crushing points, like Cleveland, Toledo, Buffalo, New York, and Philadelphia, receive Northwestern seed by lake, or lake and rail, usually from Duluth. A gradually increasing crop of flaxseed is being produced in the extreme Northwest, in the states of Oregon, Washington, Idaho, and Montana. This is marketed in the linseed-oil mills at Portland and San Francisco. The yield of oil usually obtained from this seed is better than that from the Southwestern seed but not as good as the yield from Northwestern seed. It is probable, however, that a better yield could be obtained by improved operation in the mills.

Mills on the Atlantic seaboard have no rail freight to pay on cake. Western mills must pay lake and rail, or all rail freight. The closing of the lakes each winter removes the economical advantage of lake shipments, excepting as seed or cake may be stored in quantities sufficient to tide over the period of closed navigation. Seed is usually thus stored; cake, never. The oil finds its principal markets in or near the larger cities. Boston, New York, Philadelphia, St. Louis, Chicago, and Cleveland are large markets for linseed oil.

The location of a linseed-oil mill is determined largely by the question of freights. This is the case, probably, in any business, but the matter is complicated in the linseed-oil industry because of the fact that there are three freights to consider. It is further complicated because the freight is an extremely large element in the cost of operation. In the linseed business, the raw material, flaxseed, absorbs upward of 75 per cent of the total cost, and of the remaining 25 per cent more than one-half is frequently represented by the freight expense on seed, oil, and cake. Transportation of linseed oil by pipe lines has not been suggested. The amount of oil to be transported is too small to permit of covering the fixed charges on a pipe line by the saving in freight; and the oil could not be carried in an existing pipe line used for crude or even refined petroleum, on account of the contamination of the linseed oil that would follow.

The ideal location for a mill would be at a primary seed market on the Atlantic seaboard and at a large local oil market. These three conditions unfortunately do not exist concurrently. Buffalo is a good location, having direct lake connection for seed from Duluth during much of the year, ample elevator storage for the balance, and facilities for cheap shipment of cake to seaboard by canal during the open months; and these advantages have given it several linseed-oil mills, making it the largest crushing center in the country. Cleveland has the same seed advantage as Buffalo, but not the cake advantage. It has, however, a very large local oil market and a large linseed-oil mill. Chicago has several oil mills, with a large local consumption, but is handicapped by the long cake shipment. Minneapolis has several mills, being located immediately at a seed market, but is obliged to ship out to St. Louis or the East the bulk of its oil.[1] Toledo is located like Cleveland, but without as good a local market. It has three oil mills. New York

[1] See note, page 270.

and Philadelphia pay no rail freight on cake, but both pay a large freight on seed, and neither could exist as an oil-producing center were it not for the large local consumption of oil. Boston, although a seaboard point and a good oil market, cannot support an oil mill on account of the long rail freight on the seed. New York has the advantage of receiving seed by canal from Buffalo during the open season.

The linseed industry at the present time suffers from a tendency to overproduction, due to the fact that more mills have been erected than are required to take care of the domestic demand for oil. Many of these mills are, however, disadvantageously located, a point which has resulted in the steady growth of new establishments better located. During the past forty or fifty years, while the center of flaxseed cultivation has moved from Ohio to Minnesota and Dakota, many mills have been abandoned in Ohio and Indiana, for no other reason than that agricultural conditions had left them stranded, away from a base of seed supply. Chicago was once the principal flaxseed market. If it were not for the large local consumption of oil in Chicago, the westward movement of the seed crop would have inevitably closed the crushing establishments there. While many sections of the middle West are thus dotted with abandoned oil mills, there have been new and better mills, more strategically located, under construction almost constantly for some years past. The later mills are generally of larger size and are better equipped than their predecessors. Buffalo, Cleveland, and Minneapolis-St. Paul have profited most by these new installations. Conditions change so rapidly, and mills are discontinued or enlarged so frequently, that any list of linseed crushers would soon become obsolete. The largest interest is that of the American Linseed Company, owning about sixty mills and sales stations in various cities. Many of its mills are closed, however, and it operates, more or less intermittently, only twelve crushing establishments, aggregating about 360 presses. A close competitor is Spencer Kellogg in Buffalo, who operates continuously about 140 presses, in the largest linseed-oil mill in the world. The National Lead Company has mills in New York, Philadelphia, and Allegheny. A large proportion of its product is consumed in its own white-lead factories. Aside from these three there are many smaller crushers.

Natural and commercial conditions have also resulted in a form of development in the linseed-oil industry which is strongly contrasted

with that in the larger business of crushing cotton seed. The seed of the cotton plant is readily damaged by heat or moisture and cannot, therefore, be transported in bulk.[1] Cotton-seed crushing is consequently always a local industry and the mills are generally small. The result is that the process of manufacture has not been developed as fully as in the case of linseed-oil mills. Furthermore, cotton seed is cheaper than flaxseed, and contains less oil (about 20 per cent), while the cotton-seed cake commands a higher price than linseed cake; conditions which lead to a relatively slighter emphasis on maximum yield of oil. The linseed crusher aims to obtain a yield of nearly 800 pounds per ton of seed. The cotton-seed crusher averages less than half of this and sells his oil at a lower price than linseed oil. The linseed-oil industry, as conducted in England, resembles in some respects the cotton-seed industry here. The British crusher pays less for his flaxseed than we do. He gets less for his oil and more for his cake; consequently he does not aim to secure as high a yield of oil as we do, and in this policy he is sustained by the preference of his customers for a cake rich in oil.

This country's output of cotton-seed oil is about 100,000,000 gallons annually, or nearly twice that of linseed oil. Most of this is consumed at home. No other large industry in expressing oils exists in the United States, although there are some plants treating copra, and several producing corn oil, etc.

Fig. 1 illustrates in plan and cross section the general arrangement of the crushing department of a modern linseed-oil mill in Cleveland, Ohio. The seed-storage tank is not shown, and the operation as illustrated begins with the screw conveyor supplying the roll bin. Four stands of rolls are used, two for each set of six presses. The rolls are driven from a main shaft in the basement below. The meal is spouted down from the rolls to screw conveyors, which transport it to two bucket elevators, one for each heater. The two heaters are each built in three vertical sections, separated by plates, above which revolve the cast-iron agitating sweeps. The meal, after being agitated in the top section, falls through an opening in the plate to the middle section, where the agitating process is repeated and the meal delivered to the bottom

[1] This of course applies to the decorticated seed. Large quantities of unhulled linty seed are regularly shipped in bulk from Egypt and India to Great Britain. Hulled sunflower or poppy seeds are also subject to damage in bulk storage.

section for a final mixing. The sweeps of the heaters are driven, by means of bevel gears, from the same shaft which drives the rolls. Each heater delivers meal to an hydraulically operated former. The presses hold 20 cakes each, which is about the limit without increasing the height of the press above that to which a man can comfortably lift a 20-pound cake of hot meal with its press cloth and handling pan. The settling troughs behind the presses give ample distance for the circulation of oil and deposit of sediment therefrom before the former reaches the scale tank. Two hydraulic pumps and two accumulators or hydraulic storage reservoirs are used, one of each being employed on each of the two hydraulic pressures carried. The lower pressure is applied to the formers and is also used to start the presses. The high pressure is used to complete the operation of pressing. The supply oil tank, shown between the accumulators and the hydraulic pumps, contains the fluid used as a transmission medium in the hydraulic system. The pumps are steam-driven. These are not as economical in power as belt-driven pumps, but are often used when the exhaust steam may be employed in the heaters or for warming the buildings.

It should be noted that the entire operation, from the receipt of the whole seed to the weighing of the oil, is kept distinctly separated for the two groups of presses. Each group thus becomes practically a separate mill, enabling close watch to be kept upon the results obtained.

The cake as taken from the presses passes through the space between the two groups of presses into the adjoining cake room, not illustrated. Here it is trimmed, packed, weighed, and stored for shipment. Indoor storage of oil is provided by a room located at the right of the cake room. The same room is used for the barreling and shipment of oil, tank cars being run on tracks alongside and filled with oil through a hose. The power plant and coal-storage bin are located at the right of the press room, the steam engine being directly connected to the shaft which runs through the basement of the press room. Seed is received from the river through a private elevator and stored in a steel tank holding 00,000 bushels. A 40-horsepower engine is used to drive the elevator and a Lane & Bodley heavy-duty Corliss engine for the main mill. A direct-connected engine and generator set is provided for electric lighting. The oil-pressing equipment, including five-high roll stands, heaters, single formers, and presses, with hydraulic pumps and accumu-

lators, was furnished by the Buckeye Iron and Brass Works. Three men operate each group of presses, one forming the meal, one filling the presses, and one stripping and removing the pressed cakes. A low wooden platform in front of the presses facilitates the work. A mechanical stripper is used to remove the cloths from the pressed cake. This has a capacity of about 15 cakes per minute. The cake is trimmed by a Dion & Belanger knife trimmer and packed by a French hydraulic automatic cake packer. The press plates have double hair mats. Six pressings per hour are made on each group of presses, i.e., the six presses constituting a group are each filled at intervals of 60 minutes. The yield is very good, being close to 20 pounds of oil per bushel of seed. The output, with 22-pound meal cakes, should be $22 \times 20 = 440$ pounds, or $440 \div 56 = 7.9$ bushels of seed per press per hour, or for 23 hours, 181 bushels per press per day. The mill is defective in having insufficient storage room for cake, an unfortunate feature when cars for shipment are scarce. The press room is fairly cool and comfortable, having two outside exposures.

A coal conveyor brings coal from boats in the river to the bin immediately in front of the boilers. Two boilers are used, equipped with Murphy stokers and burning slack coal. Besides the two feed pumps, the power plant contains a Cochrane open feed water heater, receiving the exhaust from the main engine. The accumulators are each of 18 tons capacity, being designed for an ultimate installation of 30 presses. At the beginning of operation, this mill maintained four tank cars, making local shipments of oil in tank wagons. Room for extension was provided at the left of the press room and cake room, and this space has recently been utilized for a considerable enlargement.

Fig. 2 gives an exterior view of a complete linseed-oil mill at Buffalo, N.Y. The special car at the right is loaded with empty barrels, destined to be cleaned, coopered, and filled with linseed oil. The marine legs from the elevator receive flaxseed from a lake steamer. The plant is of solid and substantial mill construction. Fig. 3 is a nearer view of the same establishment, taken from another point. This mill has a maximum crushing capacity of 20,000 bushels of seed per day, equivalent to 1000 barrels of oil and 350 tons of cake. It comprises practically four distinct mills, the result of gradual expansion of the business. The most recent of the four mills is driven entirely by power from Niagara Falls, utilized by rope drives from a 500-horsepower

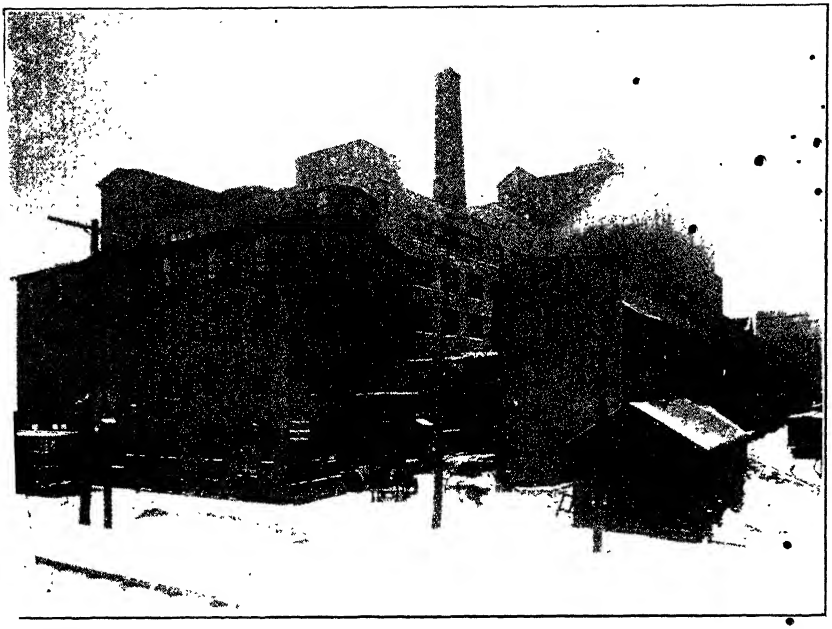

Fig. 2. — Linseed Oil Mill at Buffalo, N. Y.

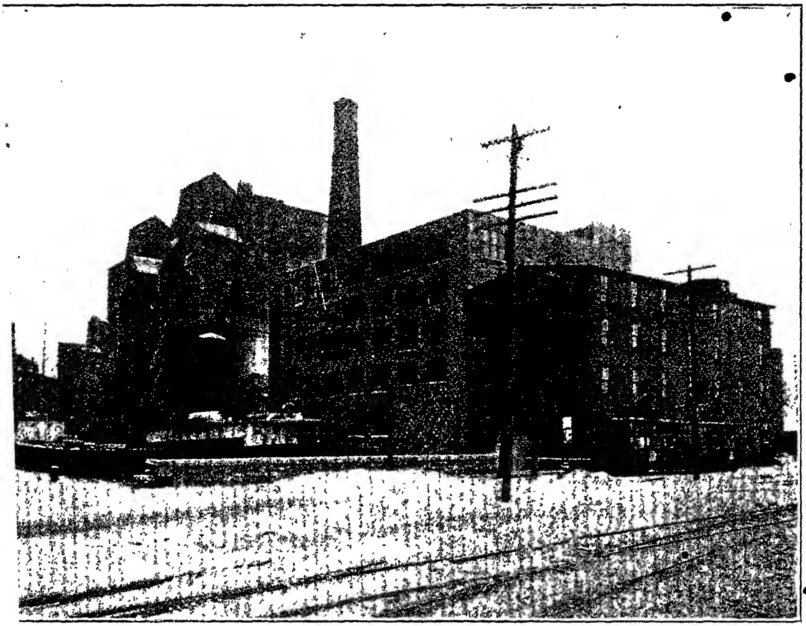

Fig. 3. — Spencer Kellogg Linseed Oil Mill.

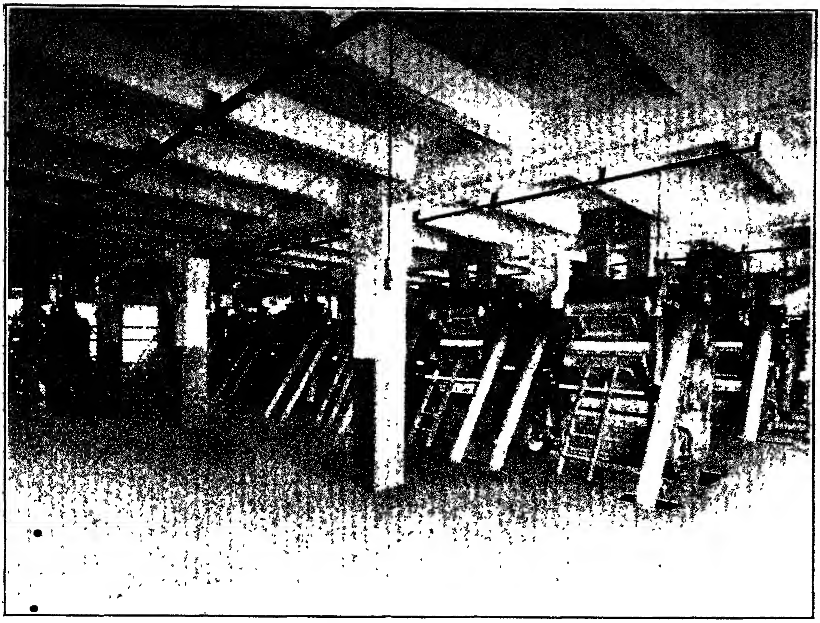

Fig. 4. — Roll Floor at Kellogg Mill (No. 1).

Fig. 5. — Roll Floor at Kellogg Mill (No. 2).

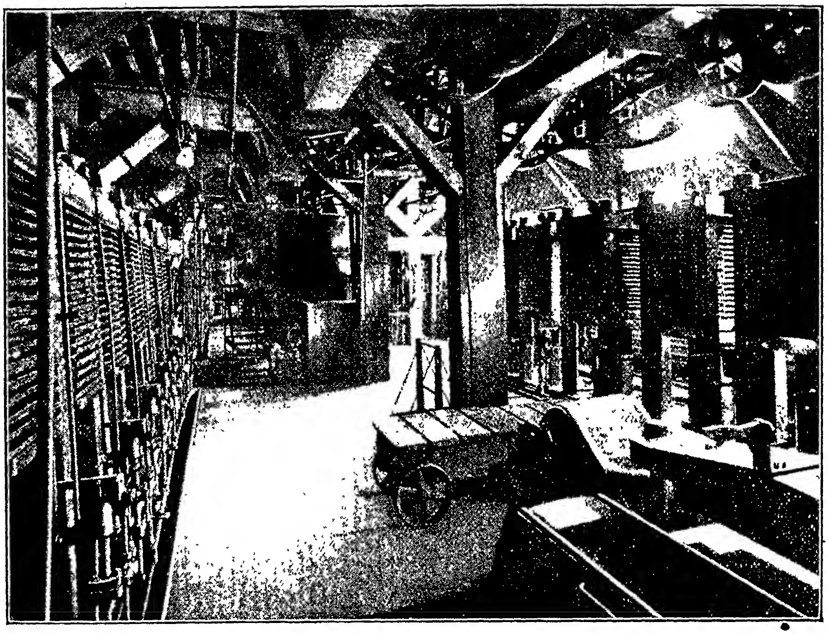

Fig. 6. — Press Room of Kellogg Mill (No. 2).

Fig. 7. — Press Room of Kellogg Mill (No. 1).

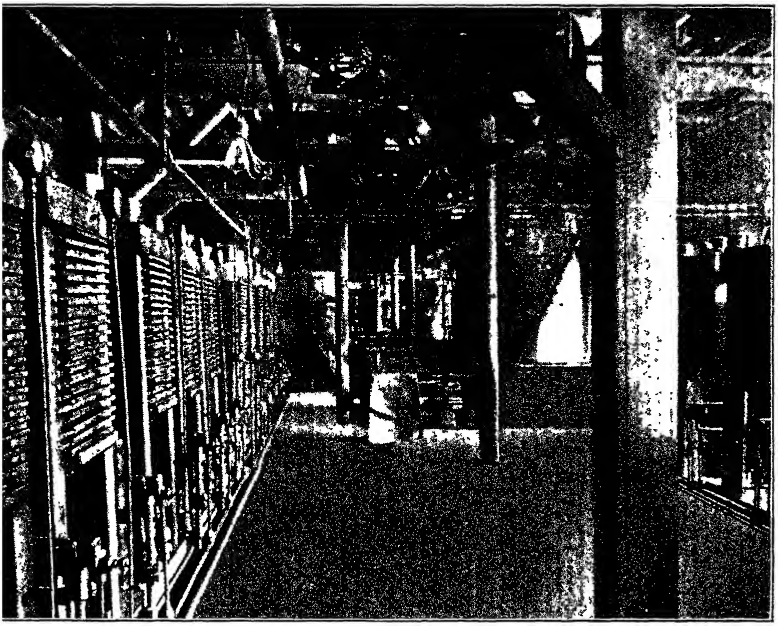

Fig. 8. — Press Room of Kellogg Mill (No. 4).

Fig. 9. — Press Room of Kellogg Mill (No. 3).

motor. Two views of the roll floor in this latest mill are given in Figs. 4 and 5. There are 24 stands of 14 × 48 inch five-high crushing rolls, each stand weighing about 9 tons, grouped in sets of seven, seven, seven, and three stands. The methods of driving and of feeding are shown by the illustrations. The belting is up from below, and twin spouts are brought down from the seed bins to each stand of rolls, each spout having a shut-off gate for controlling the flow of seed. In addition to these 24 roll stands, the three older portions of the establishment contain 45 stands of crushing rolls, making a total of 69 stands in the plant, serving 138 presses.

The press rooms are on the main floors of the buildings, one story below the roll floors. The 90 presses in the three older mills are served by 12 heaters and 12 cake formers. Three complete hydraulic plants are employed. The heaters in the new mill are four in number, 84-inch, two-high, each with a double hydraulic cake former. Each heater serves 12–20 cake double hair mat presses. Five two-pressure four-crank Buckeye hydraulic pumps supply the 2–20 ton accumulator sets. Hydraulic cake packers are used throughout. Figs. 6,7, 8, and 9 give interior views of the several press rooms. All of the presses, as shown, have automatic change cocks for transferring the press cylinders from low to high pressure at the desired moment. Fig. 7 clearly shows the appearance of the cakes after leaving the presses. In the foreground of this illustration is represented the French automatic trimmer for cakes. At the extreme right of Fig. 8, the meal heater or kettle is partly visible, with the cake former in front of it. In the center of Fig. 9, the former, with the press cloth laid in place ready to receive a meal cake, is illustrated.

CHAPTER II.

THE HANDLING OF SEED AND THE DISPOSITION OF ITS IMPURITIES.

Quantity units.—Necessity for seed storage.—A typical elevator.—Mechanical details of elevators.—Scales.—Elevator operation.—Storage of seed.—Estimating quantities in bulk storage.—Impurities.—Sifting.—Disposition of screenings.—General analysis.—Assumed cases.—The crushing of screenings.—Screw conveyor systems.

FLAXSEED is sold in the United States by the nominal bushel of 56 pounds. A long ton of seed therefore contains 40 bushels, and a short ton 35.9 bushels. A kilo = 2.2 pounds = .0394 bushel, or 25.4 kilos make one bushel. A bushel of seed produces, roughly speaking, $2\frac{1}{2}$ gallons (nominal gallons of $7\frac{1}{2}$ pounds) of oil and 37 pounds of cake. About 54 bushels of seed produce, therefore, a short ton of cake, or about 60 bushels a long ton. A barrel of 50 gallons of oil is produced from 20 bushels of seed. These relations are of importance as affecting the storage and shipping facilities desirable for seed, oil, and cake.

All linseed-oil mills are dependent upon the common carriers for their supply of flaxseed. The smallest mills use nearly a carload per day, the larger mills consuming up to ten or fifteen carloads of 1000 bushels each. A lake steamer may carry upwards of 200,000 bushels; a canal boat, of the type used on the Erie Canal, from 5000 to 8000 bushels. As the lakes and canal are closed for several months in winter, and as no common carrier is infallible in regularity, the oil mill must provide facilities for handling seed quickly and for storing it in quantities. To just what extent the equipment of the mill for unloading seed should exceed in capacity its crushing equipment, is to be determined by local transportation conditions in each particular case. Often this excess is six or eight fold: sometimes little, if any, excess is provided in cases where the transportation conditions are favorable. When seed is received by switch from a public elevator it costs usually no more to leave the seed in the public elevator for ten days than to remove it immediately after the discharge of a cargo.

The elevator equipment at one 12,000-bushel mill (daily capacity) consisted of an iron structure 20 feet 9 inches by 67 feet 9 inches,

90 feet high, containing two marine legs having a capacity each of 2500 bushels per hour, two 200-bushel hopper scales, two 2500-bushel lofty legs (elevators for raising seed from the bins under the scales), three 24-inch belt conveyors in a gallery 25 by 255 feet, running over the storage tanks, and four steel storage tanks 65 feet high, having an aggregate capacity of 650,000 bushels, arranged to receive seed from the belt conveyors. Between each two storage tanks was placed a steel elevator. These elevators received seed from the bottoms of the tanks and raised it to the conveyor belts which delivered it to a cross screw conveyor under the gallery. This screw conveyor fed the seed to a chute built of wood, thoroughly stiffened by iron truss rods and lined with glass. The chute conducted the seed to the sifters in the mill building proper. The glass-lined wood chute was found, after extended experiment, to be better than a metal spout for withstanding the action of the sharp-pointed flaxseed. As noted, there were three conveyor belts running lengthwise of the gallery, over the tops of the seed tanks. Ordinarily, only one was run for unloading seed from the boats, another was kept in reserve, and the third or middle belt was used for carrying seed from the storage tanks to the mill. Under average conditions, five hours of running per day kept the cargoes unloaded and the mill supplied with seed. The elevator was electrically driven, and the electric power was furnished from a direct-connected generating set in the main power plant, which was reserved for this specific duty. In order to operate the generating set driving the elevator at highest efficiency, it was attempted, so far as possible, to supply the mill with seed during the periods while the elevator was unloading cargoes. This gave a good load of short duration in place of a half load lasting twice as long. About 175 horsepower was used to unload cargoes, supply the mill, and drive the sifters.

A feature of this elevator equipment, not described because not ordinarily essential to oil-mill elevator operation, was an arrangement by which the belt conveyors could be reversed, bringing seed from the tanks back into the elevator tower and delivering it to chutes, which could be used to load into boats. This arrangement, with a suitable shipping scales interposed in the chutes, made the installation practically that of a public grain elevator, suitable for loading, unloading, and storing any kind of grain. A rotary screen was installed for grain cleaning, 42 inches in diameter by 20 feet long, running at 28 r.p.m.

This was covered with wire cloth in 22 × 18 inch sheets, 2 × 7½ mesh. Garners were of course used over and under each set of scales. The scales were of the usual continuous type for elevator service, the weighing not interrupting the handling of seed.

Figs. 9c and 9d represent a typical English elevator.

The horsepower required to elevate materials is theoretically equal to the weight in pounds multiplied by the height lifted per minute, divided by 33,000. For flaxseed, the horsepower necessary for N bushels per hour raised H feet would be $56\ N \div 60 \times H \div 33{,}000 = NH \div 35{,}300$. The actual horsepower used in elevation is of course greater than this, depending upon the efficiency of the elevator. The form of elevator used consists usually of an endless belt running upon two pulleys, one at the top or "head" and the other at the foot or "boot" of the elevator. The head pulley runs on a shaft which is driven by belt or rope from the source of power. The boot pulley is an idler only. A "marine leg" is an elevator designed to swing out and down through a hatch into the hold of a boat which is moved alongside the elevator tower. This form of elevator is jointed at the head-pulley shaft, and opens like a jack-knife, the elevator proper being the blade and the short chute from which it hangs the handle. Proper mechanism is provided to tip the handle forward, and to open or close the blade, so as to cause the boot to descend at any desired position crosswise of the vessel. Movement lengthwise is obtained by changing the position of the vessel itself, and for this purpose power windlasses are provided, either on the vessel or at the elevator, from which mooring ropes run to blocks on the other. Frequent adjustment of position of the boot is necessary, not only in order to unload the entire cargo, but also to keep the vessel properly "trimmed" or balanced while unloading. With large lake steamers, provided with water ballast, this shifting is almost wholly dispensed with.

The speed of the head shaft of the elevator legs is usually from 30 to 48 r.p.m. The larger the belt pulleys, the higher the permissible speed, and large pulleys consequently greatly increase the capacity. The highest efficiency is obtained when the face (lifting side) of the head pulley is vertically in line with the face of the boot pulley. Stationary elevator legs should always be set in this position. The housing of the leg should be bowed out on the back to give clearance for the sway of the belt. The pressed-steel seamless buckets are firmly riveted to the belt,

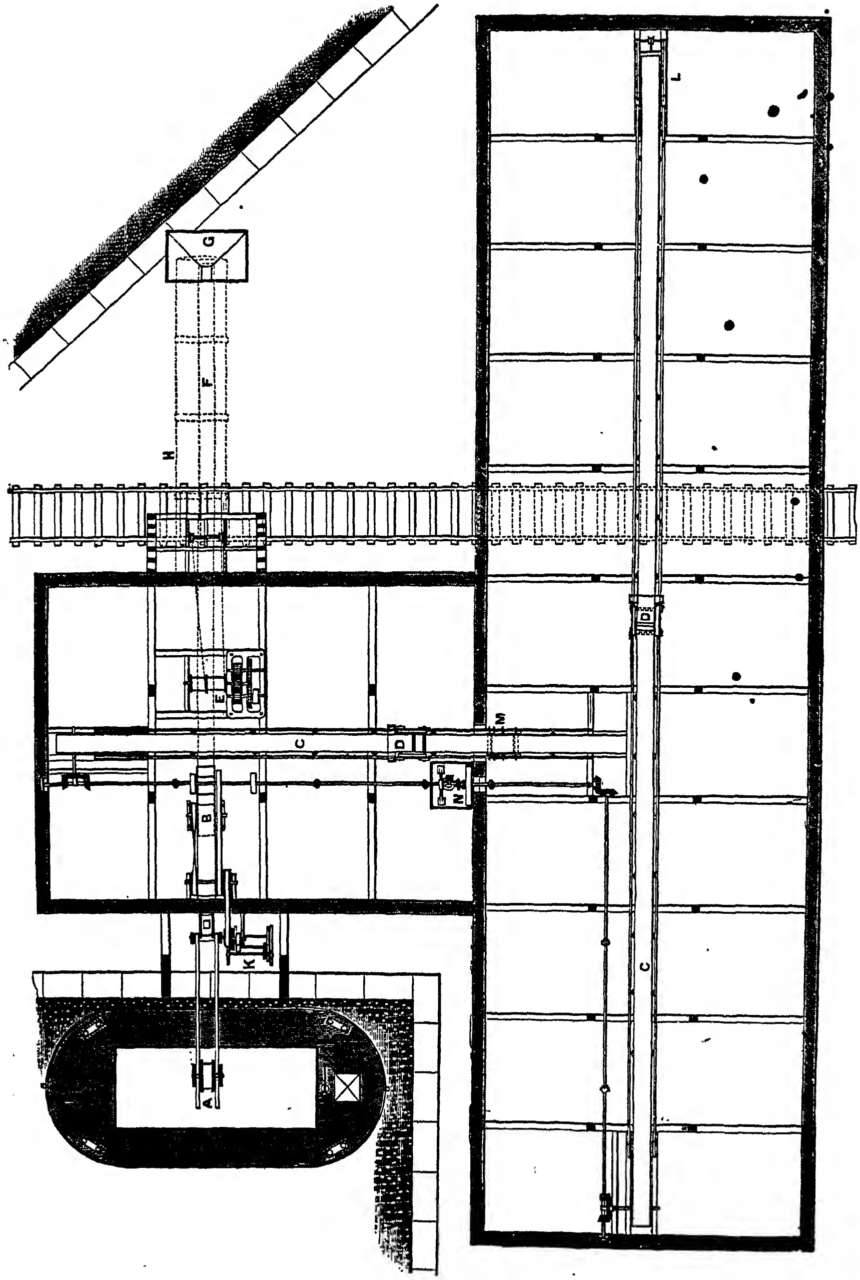

Fig. 9c. —Plan of Flaxseed Elevator. (Rose, Downs & Thompson, Ltd.)

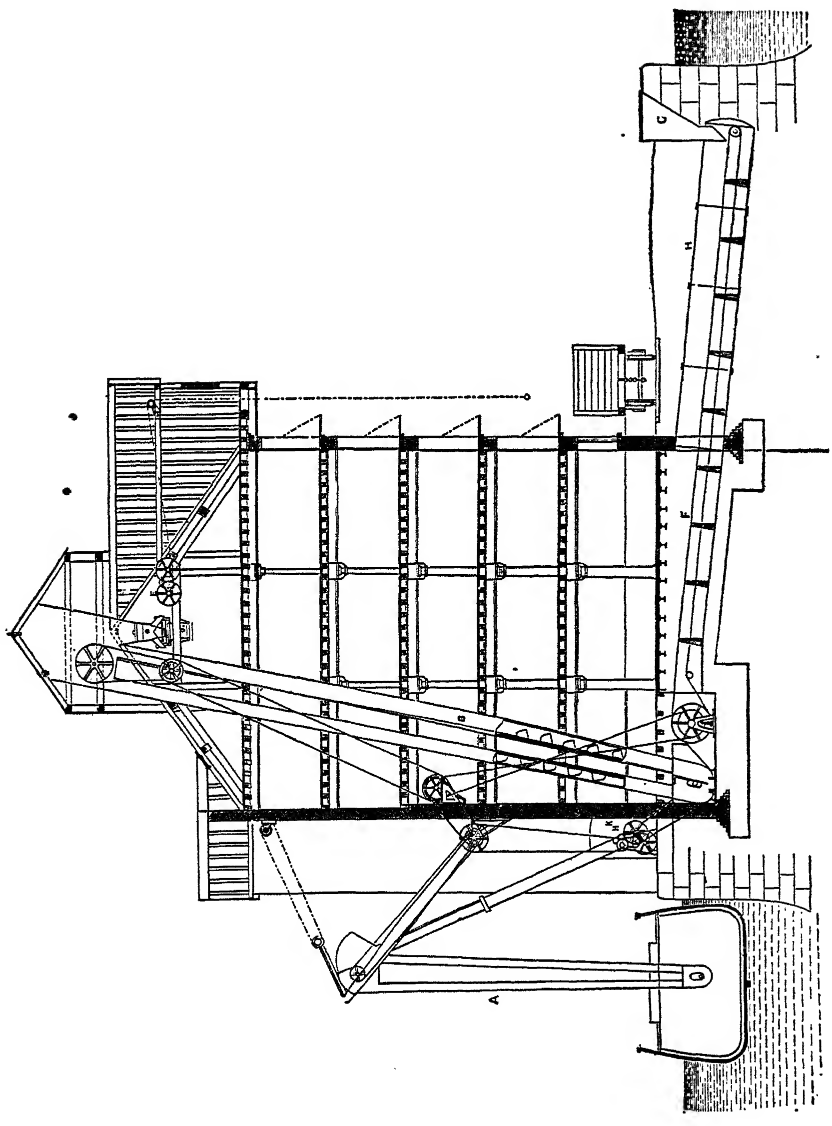

FIG. 9d. — CROSS SECTION OF FLAXSEED ELEVATOR. (Rose, Downs & Thompson, Ltd.)

and the boot should be so arranged that the grain will feed into the buckets on the lifting side at the height of the center of the shaft of the boot pulley. The capacity of the elevator depends upon the speed of the belt, the distance between the buckets, and the cubical contents of the buckets. If C = contents of each bucket in cubic feet, S = distance center to center of buckets in inches, K = speed of belt in inches per minute, the capacity in cubic feet of material per minute is $CK \div S$. For flaxseed, one bushel of which occupies a volume of 2520 cubic inches, the capacity in bushels per minute is $\frac{1728}{2520} CK \div S = .685\ CK \div S$. If D = the diameter of the head pulley in inches, and R = the number of revolutions per minute, $3.14\ DR = K$ = speed of belt in inches per minute, and the capacity in bushels per minute is $.685 \times 3.14\ DRC \div S$ or $2.15\ DRC \div S$, or in bushels per hour, $129\ DRC \div S$.

A most important feature of elevator equipment, as well as one vital in other departments of the linseed industry, is the scales. Upon the accuracy of weighing hinges all definite knowledge as to the day-by-day operation of the plant. It is not sufficient to make sure that the beam balances at zero. Test weights should be provided and used periodically. The scales must be accurate. The most satisfactory reading is that provided by an autographic scale, now largely used in grain elevators. This punches the weight on a card, leaving no room for errors due to carelessness or forgetfulness.

The elevator leg does not remove all of the seed from the hold of a vessel, nor will a carload of seed run of itself entirely out of the car into the chute leading to the boot. Hand labor is necessary, in either case, to complete the operation of unloading.

From the elevator proper, or "tower," the seed passes to the storage tanks, usually steel structures similar to gas holders, although not as large. These are set on slabs of concrete. They have closed tops and usually flat bottoms, necessitating trimming in order to thoroughly empty them. Dampness ruins flaxseed, so that the tanks must be dry. Hoppered bottoms would do away with trimming, but would reduce the capacity of the tanks while increasing the first cost. They have not been extensively used. The angle of repose of dry flaxseed is about 30 degrees. Hopper bottoms, if used, should slope at about this angle. Wet seed stands at a steeper angle.

It is generally claimed that it is impossible to accurately estimate the

quantity of flaxseed, or of any other grain, in bulk storage. Such estimates are of extreme importance to the linseed crusher, in the absence of actual weighing of the seed consumed daily. If the weight per cubic foot were fixed, it would be readily possible to make such an estimate by leveling off and measuring the contents of the various tanks. Apparently, however, the weight packed in a cubic foot increases with the height of the pile. Experiments were made by the writer to ascertain, if possible, the law of variation in density with height of pile. These gave the formula $D = .02219 + .0000163\ H$, in which D = the weight of flaxseed in pounds per cubic inch and H = the height of the pile in inches. The application of this formula outside of the limits of the experiments gave inconsistent results, showing that the law of variation of density does not depend directly upon the height, but that this law, expressed in coördinates, would be represented by a curve rather than a straight line.

Flaxseed, as received even under the best conditions, contains much impurity. The absolutely worthless fine dust and chaff are sometimes removed by exhaust fans placed at the tops of the elevator legs. Additional cleanliness is secured by passing the seed, before working, over horizontal screens, oscillated to and fro, through which the seed drops, leaving coarser impurities on the surface. These gradually dance toward the edge of the screen and are spouted away to bins or bags. They are worthless to the crusher, and the cost of removing them is more than the revenue they bring. They are taken out principally to avoid their injuring the rolls. Power for operating the sifters amounts to about 10 horsepower per 2000 bushels screened per day of ten hours. A typical sifter is shown in Fig. 9a. The sifters are usually operated during the daytime only, sufficient bin capacity being provided over the rolls to accommodate screened seed for the night run. If power for the sifters is provided by a motor, the latter should be compound-wound, as the starting load is too severe for a shunt-wound motor. The coarse screenings, if not sold, are sometimes ground with oil cake in the cake grinder, thus masquerading as oil meal for the stock-raiser. The quantity is probably too small to be detrimental. Unlike cotton seed, flax requires no special treatment by the crusher to remove adhering fiber. The seed is clean in this respect, and is crushed without hulling, the fine flaxseed hulls exerting no detrimental influence on the cake. The separation of fine impurities from the seed is usually effected,

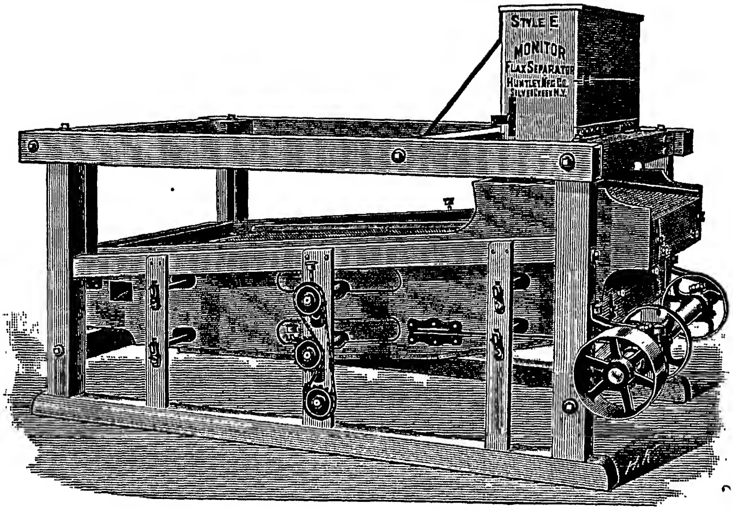

FIG. 9a. — HUNTLEY SINGLE FLAX SEPARATOR OR SIFTER.

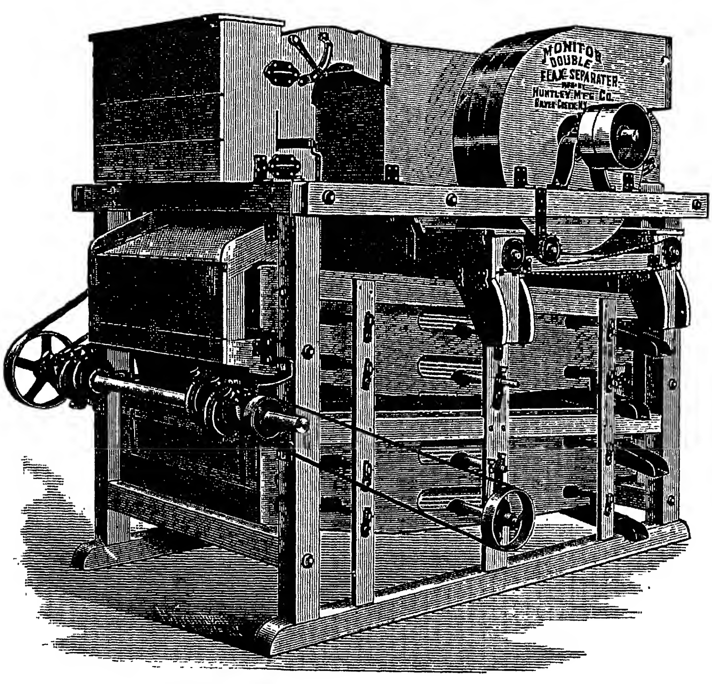

FIG. 9b. — DOUBLE DUSTLESS FLAX SEPARATOR.

in the public elevators, by machines of the type shown in Fig. 9b. These will readily clean down to 2 per cent without wasting or damaging the seed. They are double machines, with single feed, and can be arranged so that the two shakers may operate in succession, giving the seed a double cleaning. Hay, chaff, etc., are removed by air separation, a fan drawing these fine particles into a settling chamber.

Seed is purchased by the nominal bushel of 56 pounds of pure seed. Any impurities contained in the seed are the property of the buyer, without payment. These impurities all have some value. The crusher consequently receives very little screenings, unless from direct country shipments.[1] These screenings consist, besides the coarse impurities removed by the sifters, of fine matter which goes through the screens with the seed. This fine matter gives rise to the first complex problem in the linseed industry. It may be either separated and sold, run through the mill with the seed, or separated and ground up with cake. The first procedure depends upon a market for the screenings. This can usually be found, but the profit realized is not great. The second procedure risks the purity of the oil and cake. The third risks the purity of the meal, and can only be practiced where there is a sufficient market for meal to justify the installation of cake-grinding equipment. Aside from these considerations, the problem may be analyzed as follows:

Let P = percentage of impurities in the seed,
B = cost of seed per bushel, in dollars,
E = cost of manufacturing one bushel into oil and cake,
Q = percentage of impurity in seed, removed before crushing,
D = cost of delivering one bushel to the crushing mill,
F = cost of packing the cake produced from one bushel.

Then the price paid for 56 pounds (one bushel) of material, the screenings being obtained gratis, is $B \times \frac{100 - P}{100}\cdot$ The additional cost of delivering the seed, due to the presence of screenings, is, per 56 pounds, $D \times \frac{P}{100}\cdot$ The additional cost of crushing, due to the same

[1] A large proportion of the "Southwestern" seed, which is shipped direct from grower to western crushers, contains a heavy percentage of impurity; occasionally 25 or 30 per cent.

reason, is $E \times \dfrac{P - Q}{100}$; and the increased cost of packing the cake is $F \times \dfrac{P - Q}{100}$. The total additional cost due to the presence of impurities is the sum of these last three items, or $\dfrac{DP}{100} + (E + F)\left(\dfrac{P - Q}{100}\right)$. If the price obtainable for screenings is G dollars per ton, and oil cake is worth H dollars per ton (2000 pounds), then the revenue per bushel from the sale of screenings is $56\ GQ \div 200{,}000$, and the increased revenue due to the increased production of cake is $56\ H\ (P - Q) \div 200{,}000$. The gain due to the presence of screenings is therefore represented by the formula

$$\frac{56\ GQ + 56\ H\ (P - Q)}{200{,}000} - \left\{\frac{DP}{100} + (E + F)\left(\frac{P - Q}{100}\right)\right\}. \qquad (1)$$

If the screened impurities are mixed with ground cake and sold as il meal, the increased revenue per bushel is $56\ PH \div 200{,}000$, and he profit from screenings is

$$\frac{56\ PH}{200{,}000} - \left\{\frac{DP}{100} + (E + F)\left(\frac{P - Q}{100}\right) + \frac{FQ}{100}\right\} - \frac{56\ QV}{200{,}000}, \qquad (2)$$

n which last formula V = cost in dollars per ton, for grinding cake. f we now substitute actual reasonable figures for the quantities above xpressed algebraically, we shall have a tangible basis from which to raw conclusions. Let $B = 1.00$, $E = .08$, $D = .08$, $F = .01$, $G =$ 0.00, $H = 22.00$, $V = 1.50$. Formula (1) then becomes

$$.0028\ Q - .0008\ P + .00526\ (P - Q). \qquad (3)$$

f all of the impurities are removed from the seed before crushing, $P = Q$, nd formula (3) becomes $.0020\ P$; or, in other words, the additional rofit made by reason of the presence of the screenings is, in dollars er bushel, $\frac{1}{500}$ of the percentage of impurities contained; or in cents er bushel, $\frac{1}{5}$ of this percentage. Thus, a seed containing 5 per cent f impurities would be one cent per bushel more valuable than pure eed, for the assumed conditions. Suppose, however, as is more comonly the case, none of the impurities are screened out. In this case $= 0$, and formula (3) becomes $.00446\ P$; or the profit due to the

screenings is, in dollars per bushel, $\frac{1}{225}$ of the percentage of impurities contained, or more than twice as great as when the screenings are entirely removed and sold.

By treating formula (2) in the same way, we have, for the assumed values of G, H, V, B, E, D, and F,

$$.00536\ P - .00052\ Q - .0009\ (P - Q). \tag{4}$$

This expression does not take account of the slightly higher price sometimes obtained for oil meal than for cake. Using it, however, and making $Q = P$, we have $.00484\ P$, or making $Q = 0$, we have $.00446\ P$, as the relative expressions for the profit per bushel. These may be otherwise expressed as follows: when the screenings are eventually sold as oil meal, the profit, in cents per bushel, is .484 or .446 times the figure expressing the percentage of impurity in the seed, according as the screenings are all removed from the seed before crushing or all crushed with the flax. For the prices and conditions assumed, and irrespective of other considerations, the most profitable disposition of screenings is to wholly separate them from the seed before crushing, afterward grinding them up with cake to sell as oil meal. This is not as illicit a practice as it might seem, for the reason that these screenings consist to a large extent of the broken hulls of flax, and may be equivalent in feeding value to the oil cake itself.

The foregoing analysis serves to show how complicated a problem is presented to the crusher by even so simple a subject as that of screening. Formulas (1) and (2) are general in their application, and furnish data for accurate judgment as to the best policy to be pursued in any particular mill. The operation of maximum profit may be computed directly for any assigned conditions, with the screenings entirely or partly removed before crushing or run in their entirety through the rolls, heaters, and presses. Some modifying factors should be considered, however, such as the cost of screening, the possible detrimental influence of screenings-crushing on the yield of oil from the flax, etc.

A different problem presented occasionally is that of actually crushing screenings purposely purchased because of the profit involved. Seed from public elevators now seldom runs higher than from 1 to $1\frac{1}{2}$ per cent in fine screenings. This is as close to absolute purity as present equipment for cleaning can ensure. There are many incidental advan-

tages in crushing flaxseed having a considerable percentage of impurities. These impurities contain some oil. They cost, even if actually and directly purchased, practically one-fourth as much as seed, or one-half as much as cake, or one-tenth as much as oil; and when crushed, are sold as oil or as cake. Much depends upon the nature of the impurities. In some cases, it is probable that a detrimental influence is exerted on both output and yield of oil.

The following calculations represent the results of working practically pure seed containing free dockage (impurities) amounting to 2 per cent, 5 per cent of added dockage at $10 per ton, and 6 per cent of added dockage at $10. In the last case it is assumed that the yield of oil and the production will be slightly lowered.

Case I. — No Screenings.

Seed $1.00 per bushel. Contains 2 per cent of dockage, not paid for. Production per bushel = 19.50 pounds oil, 36.50 pounds cake, shrinkage 1.14 pounds, making 57.14 pounds total. Daily production 7000 net bushels = 7143 gross bushels.[1] Working cost at 6 cents per bushel = $428.58 per day. Cake value assumed at $19.00 per ton (2000 pounds).

Cost of seed	$7000.00
Working cost	428.58
Total cost	$7428.58

Pounds of cake = 7000 × 36.5 = 255,500.
Value of cake at $19.00 = $2427.25.
Net cost of oil = $7428.58 − $2427.25 = $5001.33.
Pounds of oil made = 7000 × 19.5 = 136,500.
Cost of oil per pound = $.03664.
Cost of oil per gallon of 7½ pounds = $.2748.

Case II. — Five per Cent of Screenings.

Seed $1.00 per bushel. Contains 2 per cent of dockage, not paid for, also 5 per cent of added dockage at $10.00 per net ton. Production per net bushel, from the seed, as before, 19.50 pounds of oil, 36.50 pounds of cake. Production from the 5 per cent of added dockage, 2.5 pounds of cake, making gross production per net bushel, oil 19.50, cake 39.00, shrinkage 1.51, total 60.01 pounds. Daily production, 7143 gross bushels, or 6640 net bushels. Working cost, $428.58 per day. Cake value as before. We have, in this case,

[1] The net or "pure" bushel is 56 pounds of pure seed. The gross bushel is 56 pounds of material containing seed and impurities.

Cost of seed	$6640.00
Working cost	428.58
Cost of screenings [1]	100.00
Total cost	$7168.58
Less value of cake [2]	2453.00
Net cost of oil	$4715.58
Cost of oil per pound [3]	.0365
Cost of oil per gallon	.274

Case III. — Six per Cent of Screenings.

ıditions as in Case II, excepting that 6 per cent of dockage is added instead of cent; gross production, 19.40 pounds of oil and 38.80 pounds of cake, shrinkage unds, total 60.9 pounds per net bushel. (The yield of oil is taken slightly lower, and a :r shrinkage is assumed on the screenings, to correspond with conditions met with in ce.) Daily production, 7143 gross bushels, or 6572 net bushels. Screenings added per net bushel, 3.654 pounds, worth $.01827; cost of screenings used per day, $120.07. Daily cake product, 38.80 × 6572 = 255,000 pounds. Oil product, 19.4 × 6572 = 127,500 pounds

Cost of seed	$6572.00
Working cost	428.58
Cost of screenings	120.07
Total cost	$7120.65
Less value of cake	2422.50
Cost of oil	4698.15
Cost of oil per pound	.0369
Cost of oil per gallon	.2768

SUMMARY.

Condition.	*Cost of oil per gallon.*
2 per cent seed, 19.50 yield	$.2748
5 per cent dockage added, 19.50 yield	.2740
6 per cent dockage added, 19.40 yield	.2768

The effect of adding screenings is shown to be slightly favorable to a low cost of production, even when the excessive shrinkage on the screenings is considered, provided no impairment of oil yield is produced. As soon as sufficient amounts of screenings are added to adversely affect

[1] 3.0005 pounds screenings purchased at $10.00 per ton gives a cost of $.015025 for the screenings mixed with each bushel of seed, or $.015025 × 6640 = $100 per day.

[2] Pounds of cake = 39 × 6640 = 259,000.

[3] Pounds of oil = 19.5 × 6640 = 129,500.

the yield, a decided loss is experienced. The high shrinkage on screenings is due largely to actual losses of this fine material in transportation and working. For a fuller discussion of the causes of skrinkage in general, reference may be made to Chapter X.

Crushing screenings alone, without any admixture of flaxseed, is hard on rolls and press cloths. Presses without mats are used. The cake is soft, and shrinks heavily in storage. It is ground up with linseed cake to make oil meal, the screenings cake being added to the extent of about 30 per cent. The oil is a dark, thick product, not readily marketable. Oil must be used, instead of water, for tempering the meal.

The yield of oil obtained is just about equal to the quantity of oil used in tempering. As far as the oil end of the operation is concerned, it would be just as well to mix the screenings direct with linseed meal without first crushing them. The objection to this is that the uncrushed screenings have a detrimental effect on the oil meal, due to the various seed oils which they contain.

From the sifters, the seed passes to the bins supplying the rolls. These bins should be of ample capacity to tide the mill over any breakdown in the elevating and conveying machinery. They should be built of thoroughly seasoned wood and should be hoppered. Automatic scales should be installed between the bins and the rolls. These are now produced by several makers, and are accurate and reliable. The subject of daily weights of seed crushed is of such immense importance to the crusher that no expense should be spared which will ensure the obtaining of such weights. In existing mills, the arrangement of floors and machinery is frequently such as to make the installation of such scales impracticable; but no new mill should be built without careful provision being made for scales, preferably one set for each group of rolls supplying a set of presses, from which the oil and cake may be separately weighed.

After leaving the bins, the future progress of the seed and meal is wholly by means of chutes, screw conveyors, or belt and bucket elevators. Chutes should be of thoroughly seasoned wood. Conveyors are usually enclosed in metal, elevators in wood or metal. Wooden conveyor boxes, if used, should be of prime seasoned lumber, dressed on four sides, placed perfectly level and provided with ample supports. They should be cleated across the top at intervals not exceeding four feet.

The bearing at the driving end of the conveyor should be supported independently of the conveyor box. The usual form of metal box is round on the bottom and square on the top, in cross section. The conveyor screw should be generated from a true helix, should be as free as possible from laps or rivets, should be of strong construction, and cast true to design, and should be amply supported and well balanced.

CHAPTER III.

GRINDING.

The rolls.—Method of operation.—Sizes.—Details of construction.—Location and driving.—Necessity for grinding the rolls.—"Candling."—Roll grinders.—Their operation.—Speed of rolls.—Evolution of differential speeds.—Comparative data.

GRINDING or crushing proper is performed by the rolls. The small oil-bearing particles in the seed must be thoroughly broken up if they are to part with their oil. This involves abrasion under heavy pressure. In some cases even this is not sufficient, very old or very dry seed requiring the addition of a small amount of moisture in order that it may be pulverized readily. Usually about three presses are supplied from each stand of rolls, the average capacity from a stand being about 500 bushels per day. Whenever for any reason one stand of rolls is shut down, the remaining stands supplying the set of presses must therefore be overloaded with seed, usually to the detriment of the fineness of the meal and the yield of oil. The best practice, where the presses are divided into groups of about six, would be to have three stands of rolls for each group of presses, one stand being always in reserve. The three stands should never be operated concurrently, on account of the excessive power consumption. The rolls consume a nearly uniform amount of power irrespective of the amount of seed they are crushing. When in poor condition each stand in operation may require as much as 15 horsepower.

The size, speed, and general design of the rolls greatly affect their capacity and power consumption. The ordinary "stand" consists of a small fluted or corrugated feed roll, several (usually five) other rolls below, a feed box above the stand, guide plates for directing the seed to the roll, scrapers for removing the ground seed from each roll in turn, and a stout frame or housing supporting the other parts. The rolls rest in bearings supported by the housing. Three of the five crushing rolls are caused to revolve by the application of power. These are the top, the bottom, and the middle rolls. The remaining two are moved

in the reverse direction from the other three by friction. The seed from the feed box first flows to the feed roll, by which it is distributed uniformly along the top crushing roll. Over this it falls to a guide plate, which prevents it from falling farther, and directs it to the contact surface between the first and second rolls. The rolling of these two heavy cylinders together draws in and crushes the seed, passing it through to the other side. Any ground seed adhering to the back face of the top roll is removed by a stationary scraper, and falls, with the meal adhering, to the second roll, and, assisted by a guide plate, into the space between rolls two and three. This gives it a second crushing, and with a stand of five rolls four crushings are of course received by the seed during its passage from the top to the bottom. The crushing pressure is that due to the weight of the rolls themselves, and increases by the weight of one roll at each successive passage of the seed between a pair of rolls, until at the bottom or last stage the seed is subjected to the combined weight of four rolls.

Roll stands are made in various sizes from three-high 12 × 24 inches to five-high 26 × 72 inches. For linseed crushing, the usual standard sizes as given by the Buckeye Iron and Brass Works are as follows, the capacities given being somewhat unduly conservative:

Size.					
Upper rolls	14 × 30	14 × 36	14 × 42	14 × 48	16 × 60
Bottom roll	16 × 30	16 × 36	16 × 42	16 × 48	20 × 60
Floor Space.					
Breadth	5 ft. 8 in.	6 ft. 2 in.	6 ft. 8 in.	7 ft. 4 in.	8 ft. 6 in.
Depth	4 ft. 4 in.	4 ft. 4 in.	4 ft. 4 in.	4 ft. 4 in.	4 ft. 8 in.
Height	8 ft. 10 in.	8 ft. 10 in.	8 ft. 10 in.	8 ft. 10 in.	9 ft. 6 in.
Approximate weight	13,600 lbs.	14,300 lbs.	16,000 lbs.	17,000 lbs.	23,600 lbs.
Rated capacity per 24 hours	150 bush.	190 bush.	240 bush.	300 bush.	500 bush.

The 42 and 48 inch length rolls are those generally used by linseed mills. The feed boxes are of wood and the top (feed) roll of fluted machinery steel. The feed-roll shaft is fitted with a lever-actuated jaw clutch, permitting of instant stoppage or starting of the feed independently of the remainder of the machine. The remaining four rolls, of chilled iron, are ground to the highest possible accuracy and finish. The top roll is then corrugated longitudinally. Roll shafts are of steel, forced in by hydraulic pressure. The final grinding of the rolls is done after fitting the shafts. The bearings for the roll journals are made

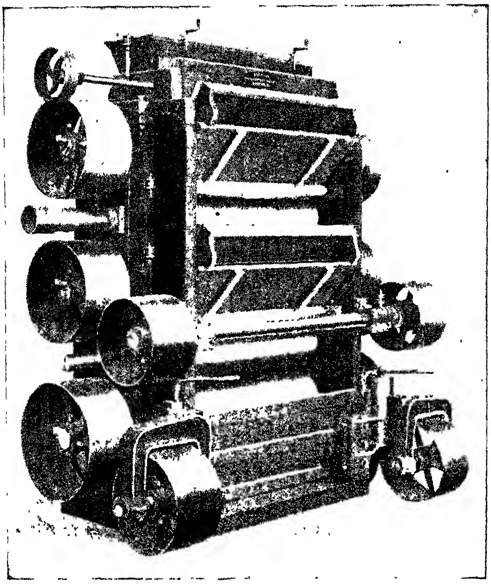

FIG. 10.—BUCKEYE CRUSHING ROLLS. UNIVERSAL TAKE-UP, SINGLE BELT DRIVE.

very large and are heavily lined. The housings are made up with machined joints, so arranged that either the front half or the rear half may be removed without taking off the feed box. Any roll can be readily removed by blocking up the rolls above. The pulleys are made of ample face for the high power delivered to them, and in the Buckeye rolls are carefully machined to diameters exactly proportional to the roll diameters. The bottom roll of the stand is usually from 2 to 4 inches greater in diameter than the others. In the more improved types of rolls, the belt alignment is secured by means of screw-actuated guide and tightener pulleys. The tightener screws are operated by ratchet handles, and permanent adjustment ensured by a positive clamping device. A stand of rolls of this design, arranged for bottom drive, is shown in Fig. 10. A simpler style, for tandem belt, with clutch control on the feed-roll drive and swing-take-up top drive, is illustrated in Fig. 11. The two styles are made in sizes from 14 × 30 inches to 20 × 60 inches. Fig. 11b shows the

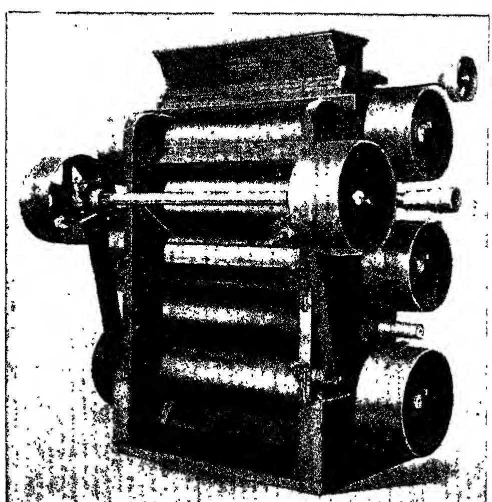

FIG. 11.—BUCKEYE CRUSHING ROLLS. SWING TAKE-UP, SINGLE BELT DRIVE.

five-high roll stand, with idler drive, built by the Platt Iron Works Company.

Rolls may be driven by rope or double belt, the latter form of drive being more common. They are usually located with reference to quick communication with the press room. In the standard type of mill, shown in Fig. 1, the rolls, heaters, and presses are all grouped in one room. This is probably the best arrangement, although it involves elevating the ground seed for supplying the heaters. Where ground space is limited, the rolls are often placed on a second floor, above the presses. The meal in this case descends from rolls to heaters by gravity, but the heavy weight of the rolls makes the building construction expensive and usually results in too low a ceiling in the press room, with consequent overheating and bad ventilation.

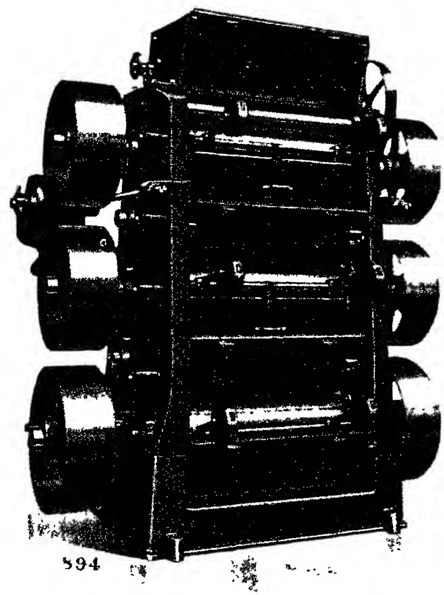

FIG. 11b. — PLATT CRUSHING ROLLS.

For fine grinding to uniform meal, the minute distance which separates adjoining rolls must be uniform along the entire width of the rolls and at all points during their rotation. This involves keeping the rolls in perfect cylindrical shape. After some months of operation, this cylindrical shape is lost. The rolls get out of true, due to a lack of perfect balance, get cut by foreign substances, and wear irregularly on account of a slight lack of uniformity in the distribution of seed to the top roll. It is usually considered that, in default of accident, a stand of rolls should remain in reasonably good condition while grinding 50,000 bushels of seed. After this they rapidly deteriorate, and this deterioration means money lost by reduced yield of oil. If working at a normal daily capacity of 500 bushels, a stand of full-sized rolls should run 100

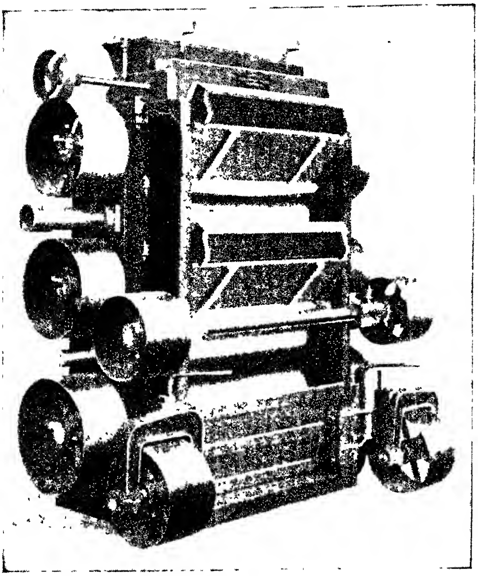

FIG. 10. — BUCKEYE CRUSHING ROLLS. UNIVERSAL TAKE-UP, SINGLE BELT DRIVE.

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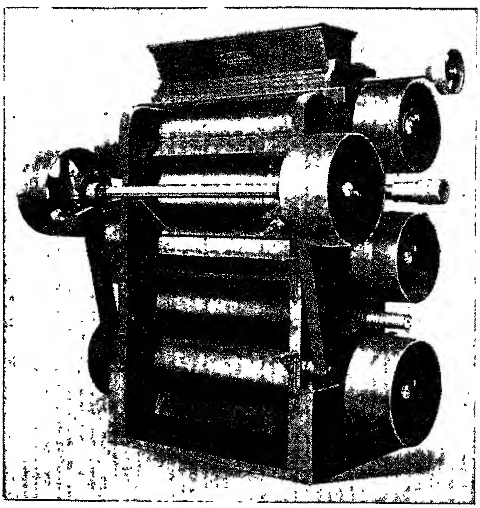

FIG. 11. — BUCKEYE CRUSHING ROLLS. SWING TAKE-UP, SINGLE BELT DRIVE.

five-high roll stand, with idler drive, built by the Platt Iron W Company.

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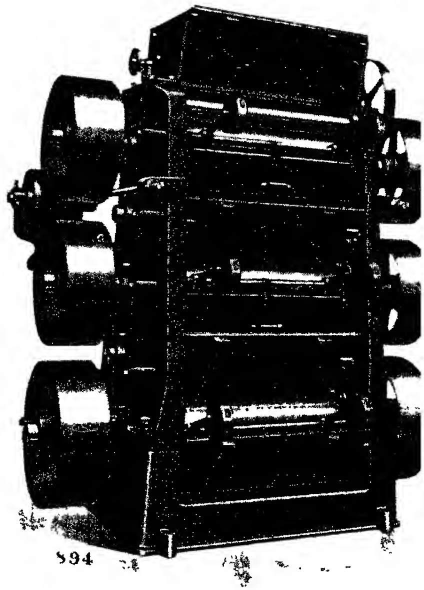

Fig. 11b. — Platt Crushing Rolls.

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days, or nearly four months, before requiring regrinding. It requires up to five days to place four rolls in the grinder and work them into good condition, so that the average stand of rolls is necessarily out of service five per cent of the time, and a grinding machine is properly continuously operated for every twenty stands of rolls.

The condition of the rolls is periodically examined by "candling." One man holds a lighted candle back of the line of contact, moving it in a direction parallel with this line, while another man looks toward the candle from in front. Any increase in the size of the thin line cf light indicates wear. If this is noticeable while the rolls are stationary, the wear is endwise; if further variation is noticed when the rolls are rotated, they are "out of true." Scratches and grooves are of course readily discerned. The condition of the rolls in general is naturally constantly evidenced by the fineness of the meal.[1]

The roll grinder should be located conveniently with reference to the rolls, as the latter are heavy, their transportation expensive, and delays wasteful. It should be set on a solid foundation, capped by a sand box to absorb vibrations and to prevent the formation of a "chattered" surface on the roll. The grinders are expensive, costing nearly $2000, and many small mills ship their rolls away for grinding, at a cost cf $10 to $15 per roll. This tends often to delay needed grinding. One type of grinder, widely used, is shown in Fig. 12. This is suitable for the ordinary sizes of linseed rolls, being known as a 16-inch solid rest grinder. It consists of a heavy single bed casting, with a movable carriage, which travels back and forth in the ways in front of the roll. There are two grinding wheels, usually of carborundum. The carriage travels automatically, reversing itself at the end of the roll. It is driven by the feed screw running inside the bed and extending its entire length. The driving mechanism, shown at the head, consists of cut gears, clutches, etc., which drive the carriage only. The wheels are driven from overhead drums, along which the belts move sidewise with the wheels. The main pulley at the head of the machine is also driven from the overhead drums and countershaft.

The rolls while being ground rest upon and revolve in their own bearings instead of upon centers, being driven by the pocket head

[1] The difficulty of accurately gauging the fineness of the meal may be decreased by first extracting the sample of oil by percolation. The residual meal particles are then much less brittle.

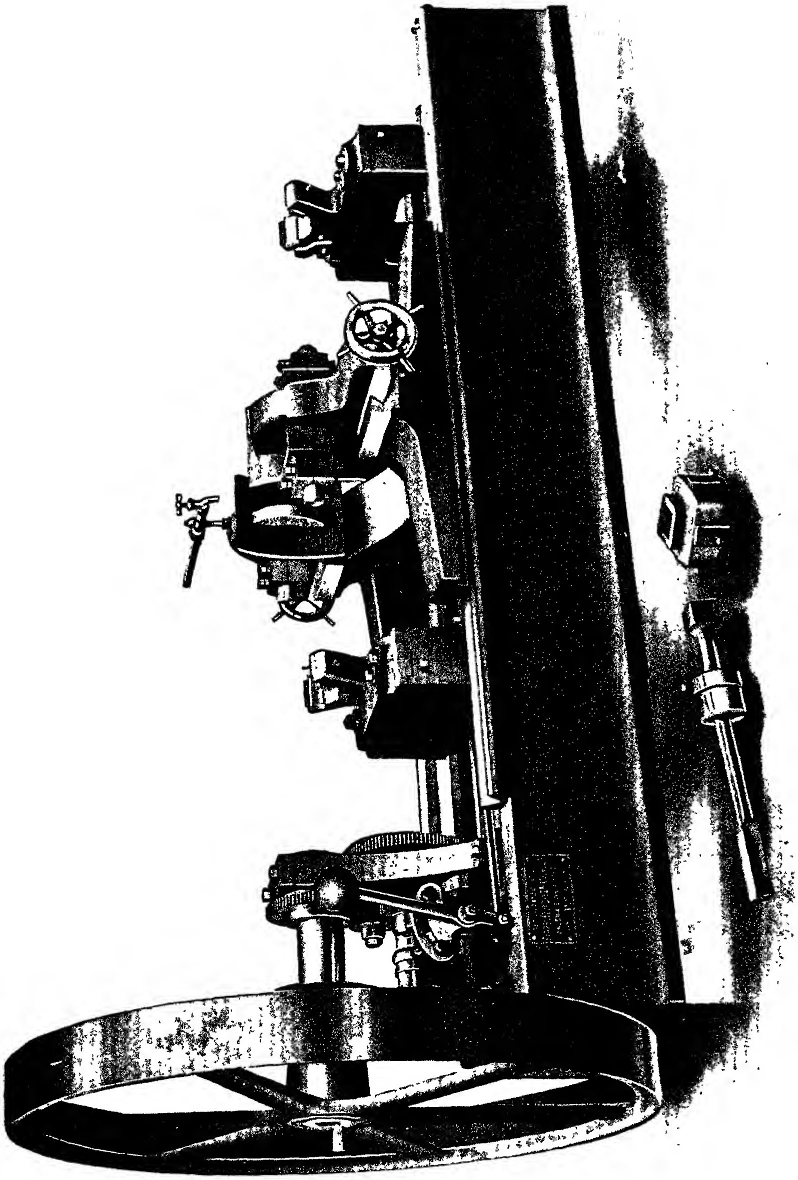


Fig. 12. — Roll Grinder. (Farrell Foundry and Machine Company.)

and spindle shown on the floor in front of the machine. The rolls are ground wet. An overhead tank, either an oil barrel or a wooden, lead-lined tank, is filled with a solution of soda-ash in water. From this tank, piping is run to faucets over the wheels. The water facilitates the grinding, and the soda prevents rust. The bed of the machine serves as a receiving tank for the soda-water, from which it is returned by a small power pump to the overhead tank.

Very long rolls are sometimes ground in a machine having a swing-rest carriage. This differs from the grinder illustrated in having the two wheels suspended upon knife-edge or V supports, on which they swing or balance in unison.

Newly ground rolls often take the seed very slowly. In order to hasten the operation of grinding, the top roll is frequently given a slight corrugation after it leaves the machine and before starting. This is done by lightly marking it with a cold chisel from end to end at several points on its circumference, using the guide-board as a rest. It is not always found necessary or desirable with chilled rolls.

Little has been said regarding the speed of the rolls. There is a difference of opinion as to what constitutes good practice in this respect. The Buckeye practice is to maintain uniform circumferential velocity. Obviously, this uniform velocity can be expected only from new rolls unless the pulleys are changed each time the rolls are ground. Some manufacturers disapprove of uniform velocities, and probably ordinary practice is away from, rather than toward, uniformity. Flaxseed was formerly ground in what are known as stone mullers (Fig. 12a), these being large disk-shaped stone wheels revolving about a horizontal axis in contact with a flat stone or iron base against which the seed was rubbed. A system of these stones, in addition to their individual rotation, revolved about a vertical axis in the center of the system, so that the seed received not only a crushing due to the rotation of a cylindrical surface on a plane, but also an abrasion due to the sliding motion of the cylinder on the plane.

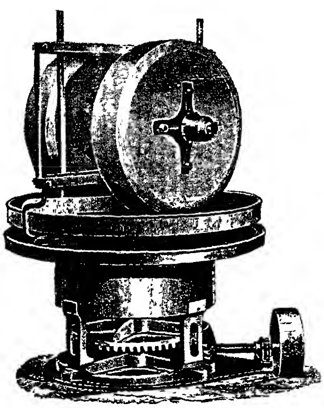


FIG. 12a. — MULLER STONES FOR GRINDING.
(Rose, Downs & Thompson, Ltd.)

Effective grinding with the modern form of roll similarly involves the running of the rolls at slightly differential speeds in order that there may be a scraping and sliding motion as well as one of simple grinding. Inasmuch as the standard dimensions for rolls are 16 inches and 14 inches for diameters of bottom and remaining rolls respectively, it will readily be seen that to obtain a sliding effect at all times between middle and top rolls, the diameters of the pulleys attached to them must be different; otherwise the idle roll between these two might make a firm contact with each and simply turn without there being any sliding, the circumferential speed of each of the three being the same. That this fact has been appreciated in the past is shown by the standard dimensions of five-high rolls built by one of the leading manufacturers. The bottom roll is 16 inches with a $22\frac{7}{8}$-inch pulley. The middle roll is 14 inches with a $20\frac{1}{4}$-inch pulley. The top roll is 14 inches with a $20\frac{1}{2}$-inch pulley. It must be remembered, however, that as these dimensions are for tandem-driven rolls, the respective rotative speeds are not simply proportional to the pulley diameters. The driving pulley for the middle roll, assuming that the thickness of belt is $\frac{1}{4}$ inch, is $\frac{1}{2}$ inch greater in effective diameter than the driving pulley for the bottom roll, and the driving pulley for the top roll is 1 inch greater in diameter. Assuming that the belt thickness is actually $\frac{1}{4}$ inch and that the bottom roll speed is $128\frac{1}{2}$ r.p.m., then the circumferential speeds in inches per minute are as follows:

Bottom roll	6459
Middle roll	6509
Top roll	6553

and the amounts of sliding are equal of course to the differences between these figures; so that the sliding between the top and middle rolls is equal to 44 inches, and that between the bottom and middle rolls 50 inches, per minute, which may be assumed to represent approximately correct practice.

It is interesting to note, however, that when one of the large manufacturers originated the single drive he failed to bear in mind this difference of speed, making the pulleys as follows:

Bottom	$22\frac{7}{8}$ inches
Middle and top	20 "

This gave practically uniform circumferential speeds of all pulleys, and was an unfortunate departure.

CHAPTER IV.

TEMPERING THE GROUND SEED AND MOLDING THE PRESS CAKE.

Operation of tempering.—Theory.—Standard form of heater.—Details of construction.—Dimensions.—Power for heaters.—Heater capacity.—Continuous heaters.—Handling wet seed.—The molder.—Its construction and operation.—Double molders.—Sizes.—Hydraulic formers.—Power formers.—Steam formers.—Desirability of an entirely automatic type of former.

THE tempering of linseed consists in submitting the ground meal to the combined influences of heat, moisture,[1] and agitation in a steam-jacketed kettle or heater, which is usually closed at the top, but is provided with doors on both top and sides, which may be opened to facilitate the regulation. In addition to the heat derived from the jacket, it is customary to inject steam directly into the meal, sometimes by means of an atomizer, spraying the steam across the stream of meal entering the heater, and sometimes by drilling a hole in the vertical shaft operating the sweeps of the heater and running perforated radial pipes out from the shaft. The perforations face away from the direction of rotation of the sweeps which afford agitation. It is also sometimes the practice to put a small quantity of *water* directly into the meal, although the generally accepted theory is that this is unnecessary excepting when working very old and dry seed.

The theory involved in the process of tempering is that the combined heat and moisture break up the oil cells, soften or dissolve their gelatinous coatings, increase the limpidity of the oil, and coagulate the albuminous sediment-forming particles in the seed, thus making it readily possible for the oil to flow out when subjected to pressure.

The standard form of heater is 72 inches in diameter, and consists of two cylindrical chambers, one above the other. Both chambers are jacketed on the bottoms and sides. The meal is fed into the upper

[1] The moisture question is unsettled. Probably the general practice is to moisten the seed, but as shown later, crushers differ on this point. Certain seeds rich in moisture, like rape and mustard, are always tempered dry.

chamber, and after having been cooked for some time is carried by the action of the sweeps to an opening through which it falls to the lower chamber, where the cooking is continued until such time as the meal is thrown out into the "former." The steam supply for the jackets is usually provided by a one-inch pipe, sometimes enlarging to one and one-quarter inches through a reducing pressure valve. When exhaust or low-pressure steam is used, the pipe connection is larger. The drips from the jackets are carried to a No. 2 steam trap with three-quarter-inch connections. A separate direct bleeder is provided in order that the temperature may be quickly brought up in starting. The steam trap cannot be worked successfully with a new heater until after several months' operation, after the sand resulting from the casting of the sections has all been blown out through the pipes. The trap outlet should be to an open well, and there must be no back pressure on the heaters.

In flaxseed milling, if the meal is taken directly from the rolls, molded and pressed, allowing the usual interval of time under pressure as in ordinary working, a cake is obtained which will show an analysis of from nine to fifteen per cent of oil. If the meal obtained in the same way is cooked, as is ordinarily done in the heater, and exposed to pressure under the same conditions, a cake showing as low as six per cent of oil will be obtained. As there is no good reason why waste exhaust steam should not be used in the heaters instead of live steam, now more commonly employed, the cost of "tempering" the seed need not be of any consequence. With proper arrangement of the supply pipes, and ample drainage from the heater, exhaust steam should supply all of the heat required. Where the vacuum system of steam heating is used for warming the buildings, as is now common, there are absolutely no complications or difficulties in the way of using the exhaust steam for the heater jackets. The steam which is injected directly into the meal must of course be clean, otherwise the purity of the oil and cake will be impaired. When exhaust steam is used for this purpose, effective oil separators or grease extractors must be installed on the pipe lines in order to ensure the removal of all traces of cylinder oil.

The object of building standard heaters in the two-high and three-high forms, rather than in a single compartment, is to permit of the more gradual and thorough cooking of the meal. The bottom compartment also acts as a receiver or storage basin, containing at all times

a large quantity of meal in proper condition for instant withdrawal to the former and transmission to the press. Good results may be obtained by cooking the meal in a single compartment, but at the expense of much closer attention and far more interference with the operation of pressing. For this reason, linseed heaters are now almost universally made two-high or three-high. The meal is fed into the upper compartment and falls continuously in small quantities to the bottom compartment, the temperature and moisture in which are regulated as desired. The sizes of compartments vary from 42 inches in diameter and 12 inches in height up to 84 inches in diameter and 24 inches in height, the most common size in recent mills being 72 by 24 inches. The standard heater compartments built by the Buckeye Iron and Brass Works consist of two pieces each, bottoms and sides being iron castings separately made, and joined iron to iron by machined surfaces. The two halves are cored independently for separate steam connections. There is thus no pressure at the joint, and no tendency to leakage of steam. The separate jacket spaces, for both bottoms and sides, permit of close regulation of the steam pressure and temperature. The inner and outer walls are stayed by pillars cast in, at about four inches distance from one another. The sweeps are of cast iron, triangular in cross section, and hollow. Occasionally they break, and all mills make a practice of carrying spare sweeps in stock. The hubs fit loosely on square-section shafts, and are driven by jaw clutches, thus permitting the sweeps to lie always close to the bottom regardless of the alignment of the shafting. The sweeps thus keep the bottoms free from gum. The supporting columns for the heaters are of cast iron, faced off square. Flange joints should be machined and drilled to template, so that the

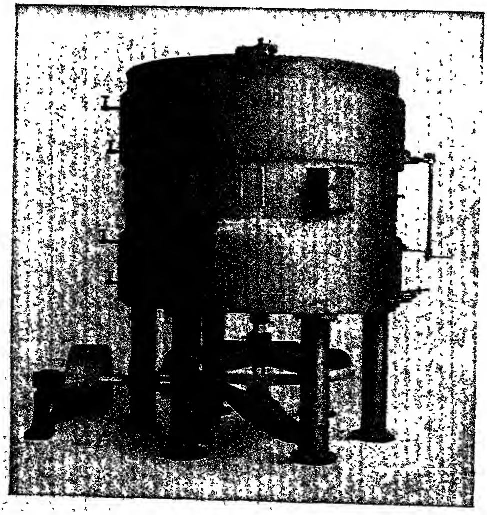


FIG. 14. — BUCKEYE TWO-HIGH 84-INCH LINSEED HEATERS.

columns will be interchangeable. The vertical shaft bearings must be lined with high-grade metal, on account of the high heat to which they are subjected. In Fig. 14 is shown a two-high heater with the usual form of driving arrangement, consisting of a bevel gear working with a pinion on a countershaft, which is belted from the main jack-shaft. The usual practice is to keep the entire shafting and gearing below the floor on which the heater stands. This heater has an enclosed space between the two compartments, thus completely separating them. This enclosed space is jacketed on the sides, like the compartments, and the flat spaces between compartments and intermediate space are hollow and filled with steam. This 84-inch heater is used in some mills for serving two sets of six presses each, but is too small for doing this amount of work where the output per press is large. It is more customary to use a 72-inch heater for each set of six presses. Fig. 15 shows the three-high 72-inch heater, with drive from below, and indicates the usual location of the cake former with reference to the heater. The two-high heater is more commonly employed when moisture is injected into the meal, the three-high being used when the meal is tempered dry. The following is the list of standard sizes of linseed heaters made by the Buckeye Company:

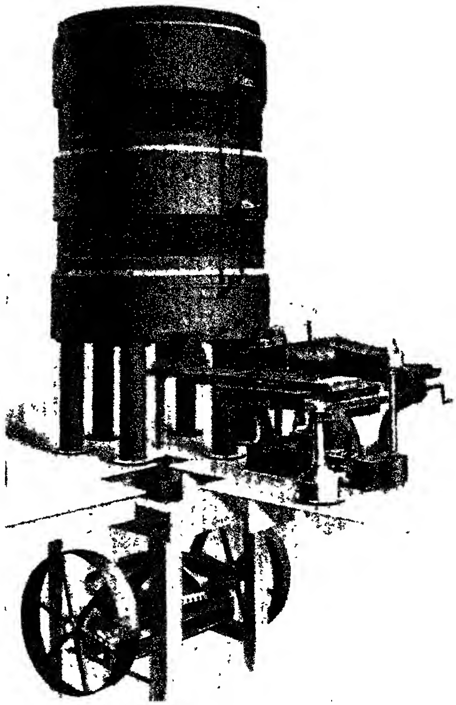


Fig. 15. — Buckeye Three-High 72-Inch Linseed Heaters, Showing Double Hydraulic Cake Former in Position. Sub-Floor Drive.

Style.	Two-High.	Three-High.	Two-High.	Three-High.
Size of compartment	72 × 24 in.	72 × 24 in.	84 × 24 in.	84 × 24 in.
Capacity per day (maximum)	1600 bush.	1600 bush.	2400 bush.	2400 bush.
Floor space { Breadth	8 ft. 0 in.	8 ft. 0 in.	9 ft. 8 in.	9 ft. 8 in.
Floor space { Depth	6 ft. 4 in.	6 ft. 4 in.	7 ft. 4 in.	7 ft. 4 in.
Height	9 ft. 9 in.	12 ft. 0 in.	10 ft. 1 in.	13 ft. 9 in.
Approximate weight	15,800 lbs.	22,000 lbs.	18,500 lbs.	29,000 lbs.

The power required for driving ordinary heaters is not great, depending largely upon the good or bad condition of the drive. In one case, a line of six heaters consumed only 21 horsepower more when running full of meal than when running light. The capacity of a 72-inch heater, conservatively estimated to allow for all reasonable variations in condition of seed, is about equal to that of six ordinary presses — say at the outside 1200 bushels of seed per day. Insufficient heater capacity ruins a linseed-crushing establishment. The meal must be properly cooked or tempered if the yield of oil is to be what it should be. Even with ample heater capacity, a slightly irregular character of meal will affect the yield to the extent of two or three per cent, with a corresponding variation in the profits from the business. In four mills which came under extended observation, the number of bushels cooked by each heater per day ranged from 1050 to 1300. The yield in the case of the mill operating its heaters at the higher capacity was noticeably less than in the other cases.

One heater is installed for each set of from five to twelve presses, being located about six feet away from the front line of the presses, and symmetrically with respect to their number. No intercommunication is provided between the various heaters, each one taking meal from a definite group of rolls and delivering it to a definite group of presses. The possible advantage of intercommunication would lie in a decreased liability to interrupted operation on account of heater breakdowns. Such breakdowns are, however, very rare, occurring sometimes at the sweep, and less frequently in the bevel gears or in the conveying and elevating apparatus between rolls and heaters. Spare gears should be kept on hand. A conveyor or elevator breakdown is annoying, but usually of short duration. The most troublesome feature in connection with any accident affecting the heater is the usual necessity for dumping the meal on the floor and subsequently shoveling it back for

retempering. This means increased cost, loss of time, and usually a noticeable loss of material.

A style of heater which has been received with favor in some cotton-oil mills, and may be developed for linseed mills, consists in what is practically a steam-jacketed screw conveyor, through which the meal is run continuously, thus avoiding the necessity for regulation, which makes ordinary methods of tempering so uncertain. It is stated that a 200-foot length of 12-inch conveyor is adequate for the tempering of the meal in a mill crushing 4000 bushels per day, and that 350 feet of 16-inch conveyor are sufficient for 9000 bushels per day. This form of heater was originally introduced by the V. D. Anderson Company of Cleveland, Ohio, and is illustrated, incidentally, in Fig. 52.

The thoroughness of tempering can be quite closely estimated by taking a sample of the meal from the heater in the bare hand. The temperature should be so high as to prohibit more than a momentary handling. When firmly compressed in the hand, the meal should form a compact, snowball-like mass, not crumbly, and the oil should ooze out quite freely between the fingers. The odor from properly cooked meal is characteristic, different from that of the ground seed, but not resembling a "burnt" odor. A good thermometer should always be connected with the interior of the lower compartment, and its indications carefully watched. Automatic regulation of temperature and moisture would be desirable for perfect tempering; but methods for producing such regulation have not yet been suggested.

Seed which has been accidentally wet is very difficult to treat. Unless taken care of promptly after the wetting it will heat, sprout, and spoil. It should be at once removed from the storage tank, spread out in a thin layer in the sun or in a dry warm room, and frequently turned over. It is difficult to grind, and requires close watching as it goes through the rolls. As it produces inferior oil and cake, it is usual to run it through the mill with at least an equal bulk of pure seed, which facilitates the grinding and tempering. The latter operation should be performed with great care, to avoid burning the seed, and more than the usual length of time should be allowed for it to gradually reach the proper temperature and to thoroughly drive off the excess of moisture. The yield from seed which has been wet is always low.

From the bottom of the lower compartment of the heater the meal passes to a box mounted on a runway over which the box travels to the

"former" or "molding machine" or "measuring frame." The box makes a fairly tight joint at the top against the bottom plate of the heater, along which a thin lever-actuated gate moves. This gate is always open, excepting when the box is traveling out to the former and back, during which operation the molder (operator) takes care to close the gate. The box thus forms practically a part of the lower compartment, in which the closing gate periodically cuts off a definite amount of meal, always somewhat in excess of that required to fill the molding machine.

The object of the former is to measure correctly and compress into convenient and compact form for delivery to the press the cooked meal from the heaters. The standard hydraulic former is essentially a table placed at a convenient height from the floor. From one end of the table a runway extends under the bottom of the heater, and on this runway moves the meal box. The table is arranged so as to lock in position at the end of the runway, and also to slide back under the stationary part of the former, consisting of a head block of heavy cast iron supported by three or four turned wrought-iron pillars. This head block is intended to withstand the upward pressure of a base plate actuated by a hydraulic ram from below. To the under side of the head block is attached a slightly concave iron plate. The hydraulic ram in the base is usually about eight inches in diameter, and is actuated from the low-pressure hydraulic system of the mill. The pressure is uniformly distributed over the surface of the cake by means of the heavy base block on top of the ram. The operation of the machine is as follows: The movable table being at rest, out in front from under the head block, a tray or pan, slightly larger than the size of cake to be made, is laid thereon. This tray is of thin sheet metal, usually of iron, sometimes of aluminum, slightly crimped up on the edges, and provided with a wooden handle. On top of the tray is spread the press cloth, about fifteen inches wide and six feet long, the two ends hanging down toward the floor. A hinged flapper frame about three inches high is now swung down on the table, on top of pan and cloth. This forms a mold for the receipt of the meal, holding it to definite size. The meal box is now run out on the runway (the gate being closed) and the meal distributed in the mold prepared for it, by two quick motions of the box back and forth. The bottom of the box is always open, but being in close contact with

the runway, no meal falls out until the box runs over the opening formed by the flapper frame. The latter being filled, the box is shoved back under the heater, and the gate opened, so that meal will be ready when required for molding the next cake. The flapper frame is now swung back out of the way, and the table with pan, cloth, and meal pushed back under the head block. A turn of the controlling valve applies the hydraulic pressure and causes the ram to ascend, compressing the meal into a moderately compact cake. Another turn, and the ram descends. The table is pulled out, the ends of the press cloth folded up over the cake, and the pressman grasps the pan by the handle and one side and lifts the cloth-enclosed cake into the press, removing the pan. Meanwhile the molder has started the preparation of another cake, using a second pan. The formers are frequently built double, one head block and ram serving two tables and operators, one being located on each side of the stationary head block. The two operators may work entirely independently of each other, excepting that one must fill his flapper frame while the other is compressing a cake over the ram. Double formers are frequently used where only one side is to be operated, in order that a reserve machine may be available in case of breakdown. The capacity of the single machine is ample for a group of six presses, and a record has been made of ten cakes per minute, corresponding to the capacity of thirty twenty-plate presses as usually worked. As one former, at least, is necessary for each heater, the hydraulic molding machine is never worked up to the limit of its capacity.

One advantage of the double former is that by properly working the press-gang of three men both sides of the machine may be operated at once, thus reducing the time necessary for charging the press, and increasing the time the cakes are left in the press, and consequently the yield of oil, without sacrificing the output. When two men share in the work of molding, it is usual to even up things by having the same two work together at some of the other operations incident to the filling and emptying of the presses.

The ram stroke should be short and quick on a former. This requires the relatively large ram, large pipe connection, and low pressure. The pressure should have choke-control to prevent jar. On the Buckeye type of double formers, the controlling mechanism is interlocked so as to prevent absolutely the possibility of applying the pressure unless one of the molding tables is fairly in position under the head, or both of them

clear out against the stops. No stroke can be made with either machine partially under the head. The meal boxes are of heavy sheet steel. The flapper frames are of wood, brass faced, and hinged to the head block. The usual cake sizes for which formers are built are 12 × 28 inches, 13 × 32 inches, $13\frac{1}{2}$ × 34 inches, and 14 × 34 inches. These are apt to undergo slight modifications at the hands of the crusher.

The hydraulic former, usually used, is rather more comfortable for the workman than the hot steam former. The pressure used is about five times higher, permitting of the use of a smaller ram. The ram stroke being only about $2\frac{1}{2}$ inches, the power consumption is slight. Some designs involve the use of a stationary ram, the ram *cylinder* moving upward with the base block or platen. This is an incidental point, depending largely upon convenience of arrangement. The cylinder and platen are made in one piece, and are heavy, so as to give a quick fall when the pressure is released. The operating valve handles are turned to either side to cause the application of the pressure, and shifted downward to release it. These handles, as shown in the illustration, Fig. 16, are pinned rigidly to a continuous shaft feathered full length, excepting for short intervals at the middle and ends.

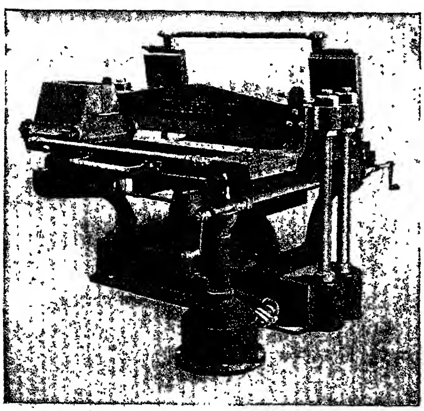


FIG. 16. — BUCKEYE DOUBLE HYDRAULIC CAKE FORMER.

Forked castings engage these feathers, the castings being attached to the molding boxes, thus preventing the turning of the operating handles at improper times. The operating valve is encased within the base of the floor stand, thus being protected from fouling by spilled meal. All pipe connections are below the floor, out of the way and secure from accident. The ram is packed with crimped leather. The dimensions of the hydraulic machines are as follows:

		Single Former.	Double Former.
Floor space	Breadth	4 ft. 9 in.	4 ft. 9 in.
	Depth	3 ft. 7 in.	5 ft. 4 in.
Height		4 ft. 4 in.	4 ft. 4 in.
Approximate weight		4100 lbs.	4400 lbs.

The power former, shown in Fig. 17, is used only in mills of small capacity. It is automatic in its movements, the lifting of the hand lever in front starting the mechanism, and the machine locking itself in the open position shown in the engraving, after the cake is formed. The pan must be laid, the press cloth spread, and the meal supplied just as in the case of the hydraulic former. The molding box is stationary, and the pressure is produced by the downward movement of the head-piece. The head recedes as it rises, so that in open position there is clearance for the full-length passage of the meal box in front. This machine occupies a floor space of 4 feet 2 inches by 2 feet 10 inches, a height of 4 feet 4 inches, and weighs 2400 pounds.

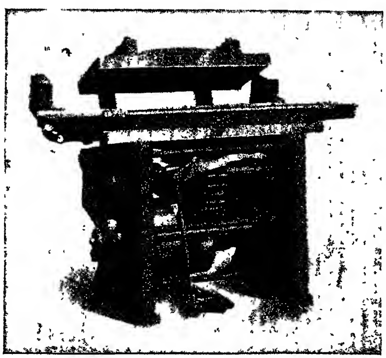


FIG. 17. — BUCKEYE POWER CAKE FORMER.

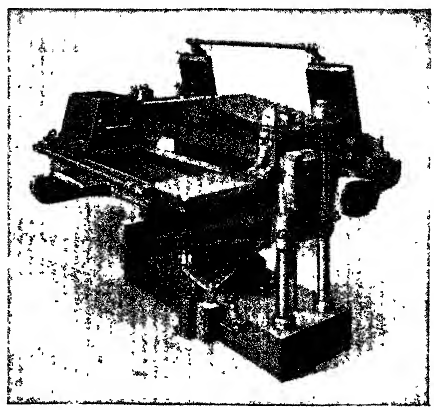


FIG. 18. — BUCKEYE DOUBLE STEAM CAKE FORMER.

A steam-operated former is shown in Fig. 18. These formers are made both single and double. The vertical stroke is $2\frac{1}{2}$ inches. The steam is gradually admitted, so as to produce compression without shocks. Provision is made for catching drips and leakage, and the latter is reduced as far as possible by using a special form of piston packing, which is forced tightly against the cylinder walls by the pressure of steam. This machine is used only in mills of small or moderate size, being more wasteful of power than a former operated from a good modern hydraulic system. The dimensions are as follows:

		Single Former.	Double Former.
Floor space	Breadth	4 ft. 2 in.	4 ft. 2 in.
	Depth	3 ft. 7 in.	5 ft. 4 in.
Height		4 ft. 4 in.	4 ft. 4 in.
Approximate weight		3200 lbs.	3700 lbs.

Fig. 18b shows a single unit heater and steam former as built by the Platt Iron Works Company.

Compressed-air formers have been used to some extent, but not largely. The hydraulic former may be considered the present standard machine. One of the largest savings possible in the linseed industry would be effected by an entirely automatic cake former and press filler, which

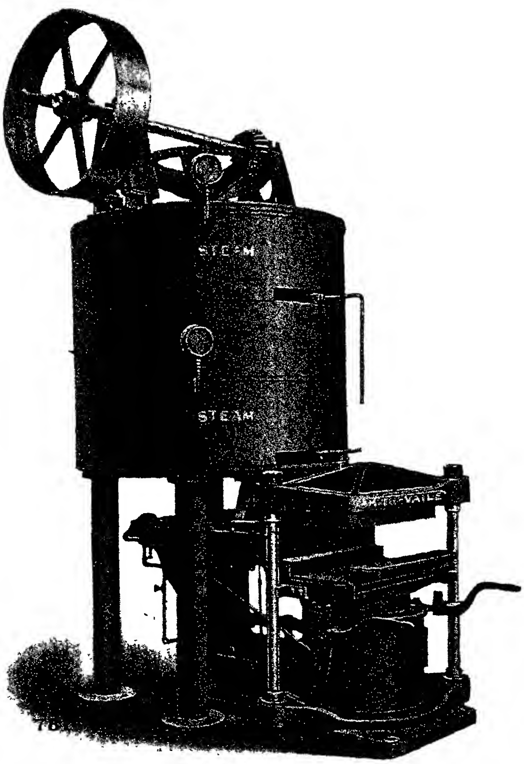


FIG. 18b. — PLATT HEATER AND STEAM FORMER.

would obviate the necessity of manual labor between the heater and the presses. This would save practically two-thirds the cost of press-room labor, or practically one-third the entire cost, within the mill, for producing raw oil and bulk cake. It would greatly reduce the time of filling the presses, remove the complicating and troublesome labor problem in the hot press room, increase the yield of oil and the output per press, and be generally desirable. The only effort yet definitely

made to effect this saving has been that of A. B. Lawther, a pioneer in the linseed industry, to whom were issued United States letters patent No. 720,532, covering apparatus for automatically extracting oil from seeds. In Mr. Lawther's invention, for several reasons, among which may be named the prime difficulty of conveying the formed cake from the place where it is made to the various presses of the mill, and the difficulty of delivering such cake to the various chambers of the press, *the presses are brought* one after another *to the cake-forming apparatus* and lowered, after lifting to full height, so that chamber after chamber of the press comes into position to receive the cake from the forming machine without movement of the latter. The cake is discharged from the presses by a similar step-by-step lowering. A stationary heater and a stationary cake-forming machine are provided, to which latter the meal is conveyed from the heater by means of a screw conveyor. A series of hydraulic presses is mounted on a turntable, which moves around on a fixed track by an intermittent motion, bringing each press successively into proper position with relation to the forming machine. The device for raising and lowering the presses is mounted on the turntable. The operation is hydraulic throughout.

CHAPTER V.

PRESSING AND TRIMMING THE CAKES.

Operation of the presses. — Time interval and output.—Influence of various factors upon yield.—Theory of hydraulic operation.—Importance of correct molding.—Weight of cake.—High temperatures necessary for good yields.—Mats.—Influence of mats on yield of oil.—Cold-pressed oil.—Permissible number of plates.—Links.—Lifts. —Reversing apparatus.—Details of construction.—Press boxes.—Plates.—Drainage.—Attachment of mats.—Press cloth.—Use of camel's hair.—Strippers.—Mechanical strippers.—The press gang.—Trimming.—General analysis.—The French trimmer.—Details of construction.—Disposition of trimmings.

The capacity of a linseed-oil mill is roughly expressed by the number of presses which it contains.[1] This is scarcely an accurate measure, because the output per press may vary 100 per cent or more, according to the size and arrangement and the program of operation. Presses are grouped in sets of from five to twelve, six being the usual number. Each set is operated by a gang, usually of three men. The presses are filled as rapidly as possible, in turn, the pressure being applied to each as filled. After filling the last press of the set, the men have a brief breathing time until the signal bell sounds for starting the filling over again. The pressure is then released from the first press, its contents removed, new cakes inserted, and the pressure again applied. The same operation is performed for each of the presses in the group.

The men work to a schedule which is expressed by the number of "pressings" or "changes" per hour. Thus, six pressings per hour means that the men fill and empty six presses in each hour. This is about the average speed of working. If the presses are in groups of six, then there is an interval of exactly one hour between the times of filling and applying the pressure on each press, during about fifty minutes of which the press is subjected to pressure. During the other ten minutes the press is being emptied and filled. If seven pressings per hour are made, and the presses are in groups of six, then the interval between fillings on each press is $\frac{6}{7} \times 60$, or 51 minutes; and if five pressings are

[1] Its output is measured by the number of bushels of seed crushed, just as that of a cotton-oil mill is determined by the number of *tons* of seed worked.

made, the interval is $\frac{6}{5} \times 60 = 72$ minutes. The amount of work done by the men depends upon the number of pressings made per hour, and is independent of the number of presses in a group. The time that the cakes are in the press, and consequently its output, are both determined by the number of pressings made *and* the number of presses in a group. Where many presses constitute a group, if a fair output is to be obtained, the men must either work harder or more than three men must be used on each press gang; in either way more pressings per hour being made.

The output of a press depends upon the time interval between fillings, the weight of the cakes, and the number of cakes per press. If N = the number of presses in a group, P = the number of pressings per hour, W = the weight of the meal cake fed to the press, in pounds, C = the number of cakes per press, then the weight of each press charge is CW, the weight of meal pressed per hour is $PCW \div N$, and the number of bushels crushed per day of 24 hours is $\frac{24}{56}$ $PCW \div N$. Conversely, if the daily output in bushels is known, say as B, then the average weight of the meal cake may be ascertained, providing the presses are working uniformly to schedule, from $W = \frac{56}{24} NB \div PC$. The number of cakes per press ranges from twelve to twenty-four; the average weight of meal per cake is from sixteen to twenty-four pounds. For the common practice of making six pressings per hour on a group of six presses, therefore, the daily output in bushels under average conditions is $\frac{24}{56} \times 6 \times 16 \times 20 \div 6 = 137$ per press. A thoroughly modern press having a capacity of twenty 21-pound cakes should crush $\frac{24}{56} \times 6 \times 20 \times 21 \div 6 =$ 180 bushels per day. In various styles of presses, the capacity over a year's operation has been found to range from 100 to 184 bushels per press per day, while the percentage of oil left in the cake was from 5.89 to 7.70. Singularly enough, the highest "cake test" was often shown by the mill working at the lowest capacity per press.

The number of plates seems to have no effect upon the yield of oil, and the influence of the time of pressing has not yet been satisfactorily determined. That there is a time below which the crusher dare not go is certain. The writer was unable to find any detrimental influence on yield of oil by reducing the time interval in one case from 84 to 60 minutes. It is probable that 60 minutes (of which 50 are spent in actual compression) is a rather longer time interval than is actually necessary; but some allowance must be made for delays which occasionally occur

in filling the presses, often resulting in a considerable decrease in the time during which the cakes are actually under pressure.

In making tests on this point, great care must be exercised to see that the number of changes per hour corresponds accurately with the actual time the cakes are under pressure, or, in other words, to see that the presses are filled in uniform time and that the hydraulic operating valves are all working alike. Provision should be made also for considering the effect of any leakage from the hydraulic system into the oil product from the presses.

The yield of oil is influenced, aside from the requirements of fine grinding and proper tempering, by the following factors: the average pressure in pounds per square inch upon the cake; the time during which this pressure is maintained; the uniformity of density of the cake as placed in the press; the thickness of the cake, or the weight for any stated dimensions and fixed operative pressure at the former; and the continuous high temperature of the meal from the time it leaves the heater until it leaves the press in the forms of oil and oil cake.

Linseed is pressed once only, although it contains fully as high a percentage of oil as some other seeds which are given two or three successive pressings in order to obtain a fractional quantity of extremely high grade oil (often edible). The single pressing for linseed is not necessarily an indication of more perfect methods of operation, although the residual oil in the press cake is kept low. The single pressing gives low cake tests at some sacrifice of the quality of the oil. Cold-pressed oil, produced by leaving upward of 15 per cent of oil in the cake, is admittedly of superior quality.

The total pressure on the cake is obtained hydraulically, the action of the hydraulic press being based on the law of hydrostatics that a pressure exerted upon a volume of liquid is transmitted undiminished and equally in all directions. Thus if we have a cylinder filled with water, in one end of which is fitted a piston one inch in area, and in the other end of which a piston having 100 inches of area travels, the application of one hundred pounds of pressure on the small piston will result in a pressure of 100 pounds per square inch on the large piston, or $100 \times 100 = 10{,}000$ pounds total. The large piston will, however, travel only $\frac{1}{100}$ as far as the small piston, as the displacements must be equal. Conversely, the application of 10,000 pounds pressure on the large piston would result in a pressure of only 100 pounds on the small piston; but

the latter would travel 100 times as far as the former. An hydraulic-press system consists therefore of a small cylinder containing a small plunger moving at high speed, connected with a large cylinder containing a large plunger moving at low speed but exerting an enormous pressure. In a linseed-oil mill, the small cylinder is the hydraulic pump, and the large cylinder is a part of the press. The pump is designed to exert a pressure of about 4000 pounds per square inch. A press ram 16 inches in diameter has an area of over 200 square inches, and the pressure which it exerts on the cakes is therefore about $200 \times 4000 = 800,000$ pounds. If this is applied to cakes of reasonable size, say $12\frac{1}{2}$ by 33 inches, having an area of 412.5 square inches, the pressure per square inch on the cakes is 1940 pounds. In order that this pressure may be steadily maintained over the entire surface of the cake, the hydraulic pump and accumulator equipment must be ample, the pipe joints and plunger packings free from leakage, the control valves tight, and the platen, or heavy block on top of the ram, by means of which the pressure is transmitted to the cakes, must be sufficiently stiff, in proportion to the length of the cake, so that there will be no flexure of the extreme ends of the platen, resulting in a reduction of the pressure at the ends of the cake. The plates and mats must also be of proper size with reference to the cake dimensions.

The questions of time of pressing and control of pressure involve some complication, and their detailed consideration will be deferred to later chapters. Uniformity of density of the cake is of great importance to good yield. Absolutely uniform cakes must be molded in the former, if uniform pressure is to be secured in the press, with consequent freedom from soft spots in the cake carrying an excessive amount of oil. Sometimes the distribution of the meal by the former is irregular simply on account of the carelessness of the operator. In one 12-press mill, the average of 16 cakes from one press gave 11.22 per cent of oil at a distance six inches from one end and 6.46 per cent six inches from the other. This tendency to irregularity is often corrected by running the meal excessively wet and applying the press pressure very rapidly in order to cause excessive spreading for filling the thin places in the cake. This is destructive on press cloths.

The effect of the thickness (or weight) of the cake on the yield has not been accurately determined. Heavier cake means larger output, and the tendency at present is toward heavier weights, say about 23 pounds,

yielding an oil cake weighing 15 pounds. At the same time, one of the largest and most successful crushers is producing oil cake weighing not much over 10 pounds, with an admittedly good yield of oil, and the small weight of these cakes appears to commend them to the foreign buyer. Further discussion will be given this subject in a later chapter.

The temperature of the meal has an important bearing on the yield of oil. It must not only be thoroughly heated in the kettle, but it must also be kept hot. The press cloth aids in retaining the heat, but a considerable loss is met with by radiation and by direct conduction due to contact with metal surfaces in the meal box, the former, and the press. This loss is most noticeable in starting up the mill on Monday morning, when everything is cold. A poor yield is then always expected. The presses are sometimes housed in to prevent currents of cold air from striking them. Some of the more recent presses have steam-jacketed side walls, which are thoroughly heated when starting up the mill. Few mills make a practice of running through Sundays to avoid the heavy loss of starting up cold; but this loss is so great that it is considered good practice, in case of a holiday shut-down on Thursday or Friday, not to run for one or two days, but to postpone starting until the following Monday. Labor conditions undoubtedly tend to influence such action.

The question of retention of heat by the meal while in the press brings up the mooted subject of mats. Modern forms of plate-presses are made either with bare plates, with mats on one side the plates or with mats on both sides. The mat, of hair on a wire base,[1] is readily detachable from the plate. It serves to rigidly grip the press cloth and the contained meal and to transmit the hydraulic pressure equally to all parts of the meal cake. The mats are larger than the cakes, overlapping from 2 to 3 inches all around. The coarse hair of which they consist is a non-conductor of heat, and the consequence of their use is a retention of heat in the meal which would otherwise be transmitted away by direct contact with the bare plates. On the face of it, therefore, the use of mats on both sides of the plates should give the highest yield of oil.

There is some objection, however, to the use of mats. They must be frequently renewed, and these renewals are expensive. A more serious objection lies in the influence of mats on the output of the press.

[1] The use of coarsely woven mats of manila rope is occasionally practiced.

The working length of the latter, or height from platen to head block, is limited by the ability of a man to lift and place the top cakes. The number of cakes which the press holds depends upon its working length and the distance, center to center, of the cakes. As the mats are of appreciable thickness, their presence increases the necessary distance for spacing the plates, and consequently decreases the output. By removing all of the mats, usually two additional cakes can be provided for in an ordinary press, corresponding to a 10 per cent increase in output. There is a further advantage due to the discarding of mats and the increasing of the number of cakes in the press. The top and bottom cakes always yield proportionately less oil than those intermediate on account of their being more exposed and their consequent quicker cooling. With a fixed loss of oil due to the top and bottom cakes, the proportionate loss is of course less as the number of cakes is increased.

When mats are discarded, the plates are corrugated to form an imprint on the cake similar to that produced by the woven mat, and thus to prevent the sliding of the press cloth. The strain on the plates is much more severe than when they are protected with mats, and they are frequently made of cast steel. The consumption of press cloth is somewhat increased when bare plates are used.

No conclusive experimental evidence has been obtained as to the influence of the presence or absence of mats on the actual yield of oil. Three days of careful observation at one mill gave average percentages of oil in cake as follows, the other conditions being kept uniform: with two mats on each plate, 6.17; with one mat, 5.87; with bare plates, 5.80. During the same period a similar test was made at another mill under the same management, giving exactly opposite results, i.e., the cake test was highest when no mats were used. The first mill commonly ran with bare plates; the second with mats; so that the result at each mill justified its own practice. The first mill regularly ran at a lower test of cake and higher yield of oil than the second when supplied with the same seed.

One of the largest crushers ran a test on this subject for six weeks, and found, after eliminating all possible conditions of variation, that the presence or absence of mats made no appreciable difference in the yield of oil. Many mills run with one mat, on one side of the plate only. A few have abandoned mats entirely. It is noticeable, however, that each mill reports results which substantiate its own practice. This is

no doubt due to the fact that the tempering which is suitable for operation with mats is not at all suitable for bare plates, and *vice versa.* The bare plates certainly radiate heat more rapidly. A higher initial temperature of the meal would seem to be necessary. This higher temperature is limited, however, to that at which the meal will be injured by the heat. The operation of tempering is more flexible, therefore, when mats are used. The increased destructiveness of the bare plates upon press cloth may be offset by the elimination of mat renewals. While the use of mats may still be regarded as standard practice, the elimination of the mat on one side of the press plate appears to offer an opportunity for increased output without departing unduly from conservatism.

The pressing of whole seed is rarely practiced in this country. The pressing of uncooked meal, making cold-pressed oil, is only occasional. The business in cold-pressed oil is so small, and the interference with his ordinary operation so great, that the average manufacturer prefers not to bother with it. Various new methods of manufacture lend themselves more readily to the economical production of cold-pressed oil, which can always be secured somewhere in the country by those who want it. The oil differs widely in its characteristics and applications from ordinary linseed oil.

The number of cakes which a press will contain depends upon the distance from platen to head block and the spacing of the plates. As has been indicated, the distance in question is determined by the limit of a man's capacity for introducing the cakes. The older presses set this limit rather low. In one old mill, the equipment consisted of presses none of which contained more than 17 plates. The maximum distance from head block to platen was 70 inches. The plates had mats on one side in all cases, and on both sides in a few of the presses.

The uniform distance-interval between the plates is maintained by means of links, which hang from pins on the side of one plate and grip pins on the side of the next lower plate. The distance center to center of link-pins, in the mill just mentioned, ranged from $3\frac{5}{8}$ inches to $4\frac{5}{16}$ inches, the greater distance being necessary when hair mats were used on both sides the plate, the lesser when mats were used on only one side. With no mats, the spacing of the plates could be still further reduced, thus increasing the number of plates in a press of given height.

The links should be readily removable, and should permit of absolute

freedom of movement of the plates, so as not to interfere with their upward travel when the pressure is applied. In many mills, it has been found that the old link spacing gave a distance unnecessarily great between the plates, and that by making new links, with a shorter distance center to center, the number of plates in the press could be increased. If this is carried too far, however, the cakes will "crowd" in entering the press, causing much annoyance and sometimes sacrificing output or yield, particularly just after the mats have been renewed.

An important feature in press construction is the proper arrangement of "lifts." These consist of forked lifting rods suspended from above the press, the forked fingers of the rods engaging the five or six uppermost press plates. By means of a small cylinder and plunger placed above the press, these lifts are held up so as to keep the upper plates in their compressed position when the hydraulic pressure is removed from the press. This leaves a good wide gap between the lower plates of the press, and facilitates the removal and insertion of cakes. When the lower plates have thus been refilled, the opening of a valve in a pipe leading from the small cylinder above the press permits of the descent of the small plunger, lift, and upper plates, which are then refilled. The pipe from the cylinder leads to a supply tank. When pressure is applied to the press again, the upper plates rise, carrying the lift and plunger with them and permitting the lift cylinder to fill with liquid. The control valve is then closed. Fig. 19 illustrates diagrammatically the usual arrangement of a press-lift system.

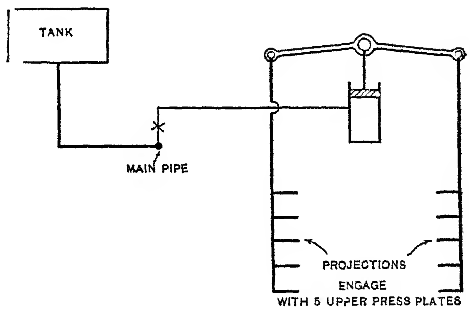


FIG. 19. — ARRANGEMENT OF PRESS LIFTS.

Another method of expediting the press operation is to provide for more rapid descent of the plates when the pressure is removed. Ordinarily, the weight of the ram, platen, plates, and cakes results in a gradual descent as soon as the pressure is relieved, in spite of the friction of the ram and of the hydraulic discharge connections. When no lifts are used, the top cake is first freed, there being maximum weight suspended from its connecting links, and the cakes are gradually loosened

from the top downward, the pressman separating the wrapped cakes from the hair mat with an edged wooden stick and carrying them to the stripping table. Where lifts are used, loosening begins with the first plate below the lifts. Sometimes the loosening operation is so slow as to cause the pressman to wait, thus giving rise to excuses for delays. To expedite this movement, the hollow ram may be filled with scrap iron, the discharge openings from the cylinder may be enlarged, a special discharge valve used, or a separate hydraulic cylinder and plunger may be used to force the plates downward. With the operative equipment in good mechanical condition, there should be no delay in the descent of the plates.

The press consists, mechanically, of a lower block or platen on top of a ram or cylinder (whichever be the movable part), a stationary head block, bolted through to the cylinder or ram (stationary part), a base plate, and the press plates themselves. In the Buckeye Iron and Brass Works' linseed press the lower block is in one piece with the cylinder, and the bolts or columns attaching the head block to the base are square, forming guides for the plates, and made of hammered iron. The columns have solid round wrought-iron nuts at top and bottom, having holes for the insertion of spanner wrenches. These nuts are locked by malleable iron bands or dogs, secured to them by set screws and having tail lugs engaging the head-block castings. The cylinders are of cast iron, tested to a pressure of 5000 pounds per square inch, and of a composition and of proportions suitable to meet this test. The base plate is cast separately, with upward projections or lugs on which the cylinder is set without fastening. It has a flange or rim around the edges, to catch any accidental drippings of oil. Drainage from the plates is provided for by oil channels made in the four sides, surrounding the cakes and pitching toward the rear, where they connect with short down spouts. A pipe runs from the bottom plate directly to the oil trough. Each fourth plate has a galvanized iron drain pan to catch the oil from its own surface and also that dripping from the three plates above.

The press plates are of either brass or steel, consisting either of plain plates or boxes with enclosed sides which nearly meet when the press is "up" or under pressure. The box plate[1] is, however, now rarely

[1] This is the press almost invariably used for cotton seed. For pressing small seeds, especially when several expressions are made, a superior quality of oil is obtained from the first pressing by using the "cage" type of press shown in Fig. 61a.

used in linseed presses. The plates may be perforated or corrugated for use without mats, or may have mats on one or both sides. The independent drainage system described makes for cleanliness, and avoids the necessity for the old-fashioned practice of setting the press so that it tips backward. Hair mats, when used, are secured in place by horseshoe nails driven through holes in the boxes. The box faces have spurs on top and bottom for holding and preserving the mats.

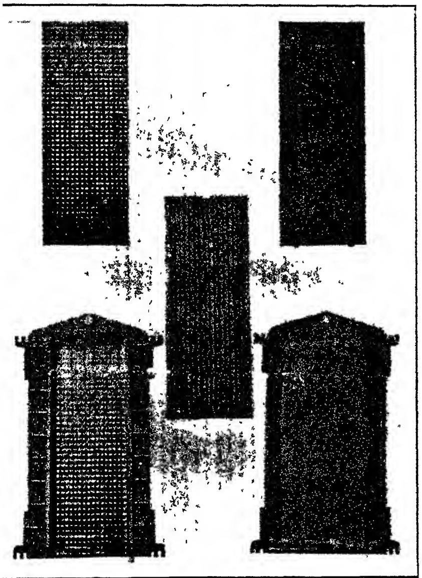


FIG. 22. — PRESS BOXES.

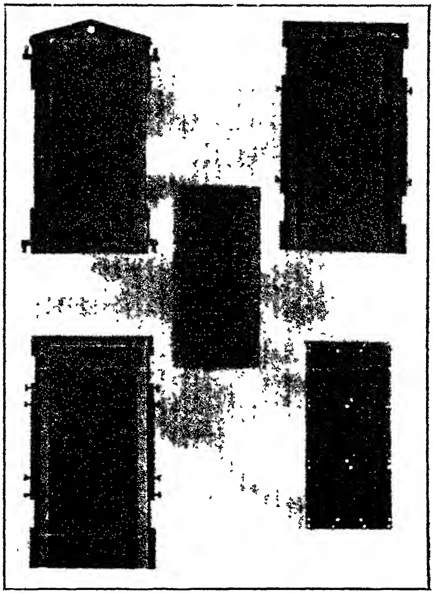
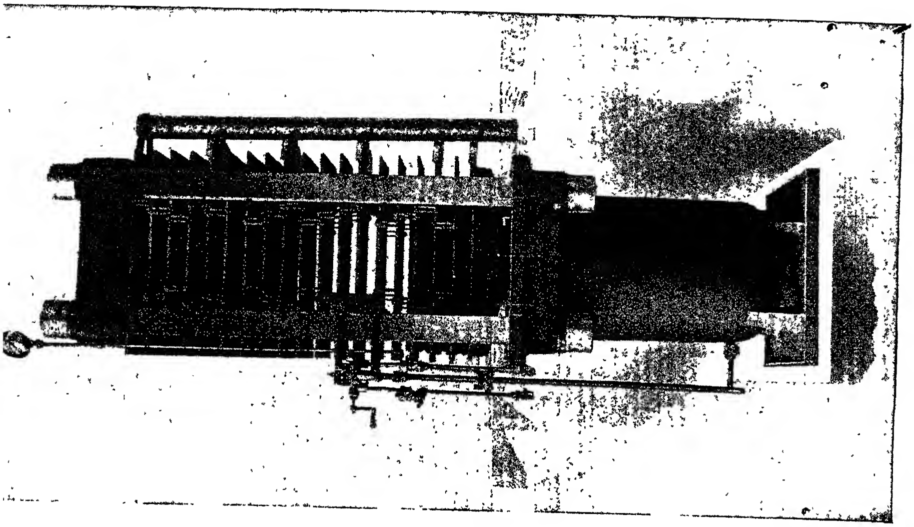


FIG. 23. — PRESS PLATES AND MAT.

The details of the press boxes are shown in Fig. 22. These are of either brass or cast steel. All have independent drainage. The brass box is a one-piece casting, but costs more than the steel box. When mats are not used, the closed brass or steel box, with steel grate and perforated brass plate, is recommended by the builders. The boxes are also built for hair mats, the construction being shown in Fig. 23.

The plate type of linseed press, now most commonly used, is shown in Figs. 24 and 25. This style is built to contain 20 cakes 13 × 32 inches in size, weighing (pressed) 12 pounds each, or the same number of 16 × 34 inch cakes weighing 16 pounds each. The plates are of steel, $\frac{5}{8}$ inch



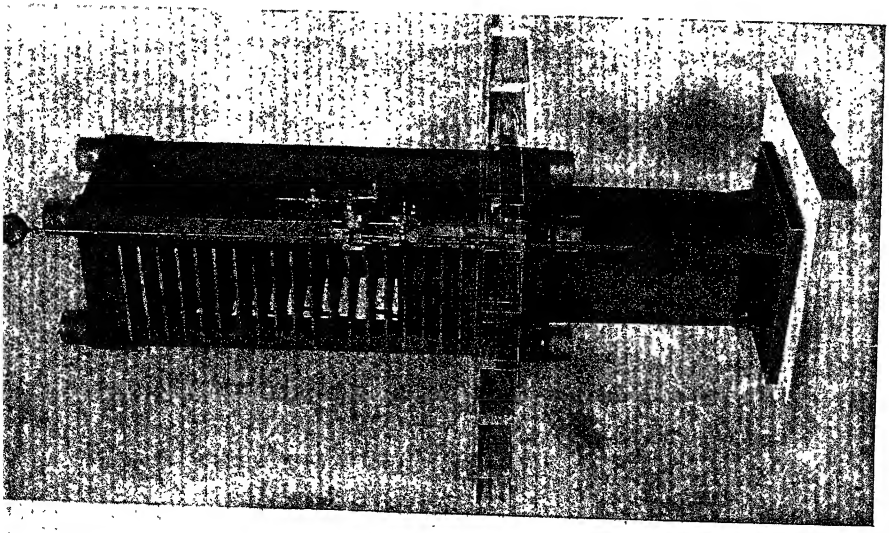


Fig. 24. P...

thick, excepting those at the top and bottom, which are 1 inch thick. Notches are milled in both side edges of the plates, to fit the square press columns, thus insuring alignment. The suspension of the plates is divided into three entirely separate groups, the top plate of the upper group being secured directly to the head block by cap screws, while the upper plates of the other two groups are fitted with lugs which rest upon the square heads of screws entering the columns at the proper positions. By this subdivision of the suspension there is avoided the possibility of straining the links sufficiently to cause crowding of even the lowest cake. Suspension of the various plates in each group is by means of plain open links of malleable iron, hung on T-head bolts screwed into the plate edges. This arrangement provides for quick removal of links or plates by simply giving quarter turns to the bolts.

Each set of 20 plates has five drain pans of heavy galvanized iron, conveying the drainage to a vertical oil-pipe, also of galvanized iron, discharging into the settling trough below the floor. The vertical pipe is so supported from above that it may be readily removed from the press. A catch-pan is provided on the platen, draining directly into the settling trough. A backward inclination of two inches is given these presses. The press occupies a floor space 3 feet 2 inches wide and 3 feet 6 inches deep, is 8 feet 1 inch high above the floor line, or 13 feet 4 inches high above the foundations, weighs 20,800 pounds, and is spaced 3 feet $8\frac{1}{4}$ inches on centers.

As most commonly used, the plates have plain faces, provided with hair mats on each side.[1] When one mat is dispensed with, the upper faces of the plates are grooved, and the mats placed on the lower faces only. The double-mat plate is illustrated in the lower left-hand corner of Fig. 23, and the single-mat plate, with grooved face, at the upper right-hand corner. Drainage channels are cut into the upper plate faces, across the front and along the sides. In these channels the expressed oil is caught and carried to the rear by reason of the backward inclination of the press.

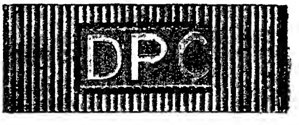


FIG. 22a. — CAKE BRAND.

Press action tends constantly to squeeze the mats outward at all edges. To overcome the effect of this tendency and to avoid in large measure

[1] The plates are sometimes made as dies so as to leave a brand on the cake. An example of a branded cake is shown in Fig. 22a. Brands are rarely used in this country.

the consequent injury to the mats themselves, mat preservers are of advantage. These are inserted beneath the mats and secured with them to the plates. The preserver is illustrated at the lower right-hand corner of Fig. 23. This is of heavy sheet steel, with a system of spurs raised by partial punching. All of these spurs are pointed inward from the four corners of the sheet, so as naturally to oppose spreading of the mat, into which they imbed themselves. Large holes, matching the smaller ones through the plate itself, allow free passage of the regular mat fastenings.

In central position on Fig. 23 is shown a hair mat. These mats are of the best possible grade, of long hair, closely and firmly braided. Boxes, plates, preservers, and mats for linseed presses are made in sizes 12×28 inches, 13×32 inches, $13\frac{1}{2} \times 34$ inches, and 14×34 inches.

The press cloth, in which the cakes are enclosed while in the press, constitutes one of the largest items of expense in a linseed-oil mill, sometimes amounting to as much as one-sixth of the entire labor cost, or one-half of the cost of steam. The cost is largely affected by the treatment which the cloth receives. Meal containing too high a percentage of moisture, worn-out mats, or too quick an application of the pressure, are all destructive. As the cloth wears at the bend over the ends of the cake, it should be pieced with sections of new or worn cloth, a small power-driven sewing machine being usually employed, and camel's-hair twine being used as thread. The limit of life of a press cloth until mending becomes necessary is seldom over six weeks; the cloth amounting to about 2 yards, or 4 to 5 pounds, per cake, worth say \$3.00, its cost has then been applied to say $24 \times 6 \times 6 = 864$ cakes, or a maximum of 432 bushels of seed. The cost of the cloth is then $\$3.00 \div 432 = \$.0069$ per bushel. This is somewhat reduced by piecing the worn cloths, as above described, but does not average much less than $\frac{1}{2}$ cent per bushel.

Press cloth is usually woven from camel's hair, in rolls of widths suitable for the cake, which are cut off to proper length in the mill. Camel's hair does not make as strong a cloth as can be produced from sheep's wool, and the camel's-hair cloth is not fitted to withstand a direct tensile strain such as is imposed when for any reason the cloth slips in the press. The peculiar properties of camel's hair make the latter, however, highly desirable as a material for press cloths. It is

very elastic, retains its form and strength under great pressure, and above all, withstands to a remarkable degree the influence of heat, being one of the very few fibers which retain their strength at high temperatures. Manufacturers would be glad to discover a quality of wool that would supplant camel's hair. The camels are yearly decreasing in number, as railroads are becoming more numerous in the far East and gradually supplanting the old caravans. Meanwhile the demand for press cloth is steadily increasing. A heavy import duty is paid on any press-cloth material imported; this, however, is subject to a drawback based on the exportation of the cake produced.

The press cloth, besides enclosing the meal cake and facilitating its ready introduction to the press, serves as a filtering material through which the oil passes on its journey from the meal. A fairly close-woven cloth is therefore desirable. There are various styles of weave used in various mills, the difference being due to individual preferences and slight differences in the grade of seed, the mats, the tempering, etc. Various weights of cloth are also obtainable in the standard widths and weaves. The camel's-hair cloth is less generally used in Europe than in this country.

Excessive spreading of cake in the press, due to improper forming, often the result of a lack of sufficient capacity in the former meal box, results in rapid destruction of the press cloth by subjecting it to tensile strain. The spreading of the cake also forms enlarged ends, beyond the ends of the mat, increasing the strain on the cloth and the amount of unpressed meal to be trimmed from the cake. When the cloth is cut so short that the ends do not meet, a high percentage of oil will be found in that portion of the cake not completely enclosed by the cloth.

The cakes taken from the presses must have the press cloths removed. Usual practice is to pile the cakes with their closely adhering cloths on a table which is mounted on rollers. This table is rolled up close to the press until the latter is emptied, then rolled away to a cooler and more convenient place, where the cloths are stripped off and passed back to the former. This is hard work, and mechanical strippers have lately been introduced in some mills. One type of stripper consists of two roughened rolls, the upper of which is stationary and mounted between the stripping table and cake truck or trimmer, while the other moves up and down as actuated by a foot lever. The workman tears or strips one end of the cloth from the cake, and passes this end under

the stationary roll, meanwhile pressing the lower roll up against it with his foot. The two rolls, which revolve by power, tear the cloth from the cake, depositing it on the floor and passing the cake itself over and on to the cake truck or to the trimmer.

Standard press-room practice formerly involved the use of three men on each press gang—one molding the cakes, one filling and emptying the presses, and the third stripping, trimming the soft edges from the cakes, and carrying them to the cake truck. This was found to give the first man a little the easiest job, hence he was called upon to "spell" the third man. The three must work together, excepting that the cakes need not be stripped and trimmed quite on schedule time. In case of the work being slightly delayed, this part of it may consequently be neglected for a few moments, the third man assisting in the molding, where double formers are used, or in filling or emptying the presses, and thus working the gang up to the signal bell schedule again. Usually the press gang has nothing to do with the tempering of the meal, this being attended to for the entire mill by some one responsible man. With the advent of mechanical trimmers, some rearrangement of the press gangs has been made. A few mills still work three men, on the old system; some work three men, but have increased the number of pressings per hour; others have reduced the gang to two men, or two and one-half, letting one stripper do the work for two press gangs; and with automatic trimmers, mechanical strippers, and other improved appliances, and with better press-room conditions, the tendency is now toward the reduction of the gang to two men, excepting when more than six pressings are made per hour.

The cakes as discharged from the press have soft rough edges, containing a relatively high percentage of oil. In order that this oil may be reclaimed, and that the cakes themselves may be fairly uniform in size, permitting of better packing, the soft edges must be pared or trimmed off. The original form of cake trimmer was a stationary knife, imbedded in a shallow trough at one side of the stripping table. The cakes were passed by hand lengthwise of the trough, one edge after another being thus pressed against the knife edge until all four were trimmed. This was laborious and failed to trim the cakes to uniform size. There was little, if any, variation in depth of trimming to suit the softness of the cake. Another form of trimmer was power-actuated, a guillotine blade falling upon the end of the cake when

presented by the operator. Usually the cake was stopped by a rest behind the blade, which thus regulated the extent of trimming. Aside from the saving in labor, which benefited the employee rather than the manufacturer, this machine had no advantages over hand trimming.

The rotary trimmer was practically the same as the original hand trimmer, excepting that the stationary knife blade was replaced by a rotating cutter, formed of four blades firmly secured to a square shaft. This machine is rapid and uses but little power. To some extent, it follows the line of hardness adjacent to the soft edges of the cake, and thus cuts to a depth which is regulated by the percentage of oil. Its capacity is large, and its introduction usually resulted in some net saving in labor, as one man could trim the cakes from two or more sets of presses. The oscillating knife trimmer, used to a slight extent for a few years, was a dangerous, awkward machine with no practical advantages over hand trimming.

The automatic trimmer, the rapid development of which is mainly attributable to A. W. French, although progress along similar lines was subsequently made by Dion and Belanger of Chicago, conforms to the theoretical requirements of ideal trimming. The cakes are automatically conveyed to and from the trimmer; the cutters are mounted on pivots and backed by springs, so that they are free to sway slightly back and forth, following the line of junction of the harder and softer portions of the cake. By altering the tension of the springs, the trimming can be adjusted to any desired limiting percentage of oil in the cake. While the amount of power consumed is small, one machine has a capacity easily parallel to that of a 36-press mill, and can be operated by one man, who, actually, does not operate the machine so much as some of the auxiliary equipment which is required no matter what type of machine is used. Large savings in labor are consequently possible when this form of trimmer is employed.

No mill could afford to operate without trimming its cakes. Granting the necessity of trimming, it is logical to trim as closely as possible; i.e., to pare the edges to such a point that the edge of the cake will contain no higher percentage of oil than the center. The only modification of this conclusion that is permissible is that which is due to the additional cost of trimming and of disposing of the trimmings. As this cost is practically that of press-room operation, say not over 2 cents per bushel, while the total cost of operation to produce bulk oil in a linseed-oil busi-

ness runs up to 10 cents or more per bushel, the cost of working over trimmings is about one-fifth that of working seed, and trimmings are consequently profitable material to work when containing one-fifth as much oil as the seed, or say from 7 to 8 per cent. The French Oil Mill Machinery Company quotes tests made of a large number of cakes from different mills, showing that the percentage of oil in the trimmings as cakes were ordinarily pared was seldom less than 20 per cent. The average of ten tests showed that .41 pound of meal was trimmed from each cake, this meal testing $22\frac{1}{2}$ per cent of oil. Assuming these conditions to be correct for average operation, and that the trimmed cakes, weighing 14 pounds each, contain 6 per cent of oil, then there are contained in the trimmings from each cake, $.41 \times .225 = .092$ pounds of oil, or from each pressing on a 20-cake press, $.092 \times 20 = 1.84$ pounds of oil, or from one day's operation of such a press at the rate of one pressing per hour, $1.84 \times 24 = 44.1$ pounds or 5.9 gallons of oil. With oil at 45 cents per gallon, this quantity of oil reclaimed is worth $2.65. This is the saving due to proper trimming, on a single press. The output of such a press being $20 \times 14 \times 24 = 6710$ pounds of cake, or say 3355 pounds of oil, or 447 gallons per day, the saving by working up the trimmings is 1.32 per cent. This is of course the gross saving and does not consider the cost of working over the trimmings, nor the value of the trimmings as cake. To make the analysis general, let

W = weight of cake, in pounds,
T = weight of trimmings from each cake, in pounds,
P = percentage of oil in trimmings,
C = price of cake per 2000 pounds, in cents,
O = price of oil per gallon of $7\frac{1}{2}$ pounds, in cents,
K = cost of working over trimmings, in cents per bushel.

Then the oil in the trimmings from each cake $= TP \div 100$, worth $TP \div 750 \times O$. The cost of reclaiming this oil $= TK \div 56$, while the value of the oil as cake would be $TP \div 100 \div 2000 \times C$. The profit per cake by working over the trimmings is then, in cents, $T\left(\frac{PO}{750} - \frac{K}{56} - \frac{PC}{200{,}000}\right)$; or the profit in cents per bushel of trimmings crushed is $56\left(\frac{PO}{750} - \frac{K}{56} - \frac{PC}{200{,}000}\right) = .0748\ PO - K - .00028\ PC.$

For $O = 45$, $K = 4$, $C = 2000$, this becomes $3.36\ P - 4 - .56\ P = 2.80\ P - 4$. For the average conditions found by the French Company, the net profit, therefore, resulting from trimming, is $(2.80 \times 22.5) - 4 = 59$ cents per bushel of trimmings. If the soft edges amount to more than .41 pound per cake, or contain more than 22½ per cent of oil, as is frequently the case, the saving due to taking care of the trimmings is even greater than this.

Cake containing a high percentage of oil is of course more in demand than cake containing only 6 per cent, and commands a premium in the foreign market; but a loss of 1 cent per bushel in crushing seed would require a premium on the cake of more than 50 cents per ton, in order that it be offset.

Fig. 26 illustrates the latest form of French trimmer. This has a nominal capacity of 20 cakes per minute, or say 60 pressings per hour,

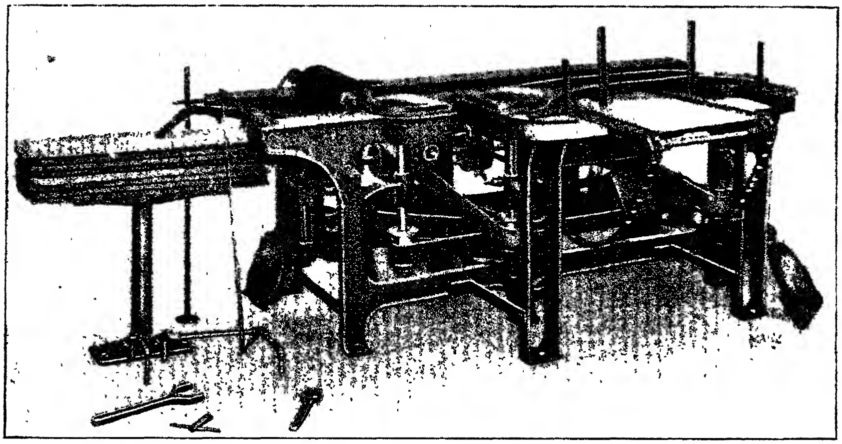


FIG. 26. — FRENCH AUTOMATIC CAKE TRIMMER.

practically that of a 60-press mill. The floor space required is 4 feet 8 inches by 4 feet 4 inches, over all. The shipping weight is 1300 pounds. The power required has been shown by actual test not to exceed 2½ horsepower when running empty and 4⅛ horsepower when the four sides of cakes were being trimmed. This of course does not include power required to drive any external conveyors. The machine is self-contained and requires no special foundation. The cakes are piled by the stripper on the machine, which automatically draws one

cake at a time from the bottom of the pile, centering it as it travels to the revolving cutters on either side. These cutters are movable and are held from opening too far from the cakes by adjustable spring tensions which compel them to follow the outlines of the cake edges, removing the softer portions and leaving the hard undisturbed. The cakes are then automatically piled on a table which forms a part of the machine and which is lowered an amount equal to the thickness of the cake each time a cake is delivered to it; or the table may feed directly into the cake packer; or in some cases, when the packing is not done immediately after trimming, the trimmer delivers to a link belt conveyor, which carries the cake to the cake house. The table accommodates from 40 to 60 cakes at a time.

The trimmings are very fine. All belts are encased to protect them from being affected by oil meal. The cutter knives should be ground frequently to ensure economy of power. The machine will trim a cake broken in two, but not small broken pieces. In some mills the meal is so tempered, and the application of pressure so regulated, that hard ends are formed on the cake, and trimming is not highly profitable from the standpoint of oil recovery; but a high price is paid for this practice in increased consumption of press cloth.

With most trimmers, the parings from the cake are full of small lumps. If these were returned directly to the heaters, they would interfere with the operation of tempering and prevent the formation of a uniform cake. A small grinding mill is usually mounted under the trimmer. The trimmings fall to this mill by gravity, and a grated manhole is usually located in the floor, so that spilled meal may be swept into a chute which will deliver it to this same mill. From the mill the uniformly ground meal is carried by screw conveyors and belt or chain elevators to the heaters, from which it passes once more through the usual process of expression. This return of meal of course detracts from the theoretical capacity of the presses, usually from 3 to 4 per cent.

CHAPTER VI.

HYDRAULIC OPERATIVE EQUIPMENT.

Units involved.—High and low pressure.—Control of pressure application.—Regulation of pumps.—Pump connections.—The four-crank hydraulic pump.—Its operation.—Details of construction.—Hydraulic-pump capacity.—The accumulator.—Accumulator details and connections.—Compressed-air accumulators.—Relations between amount of pressure and ram and plunger diameters.—Dead-weight accumulators.—Sizes.—The automatic change cock.—Early forms of automatic control.—The French valve.—Graphical record of pressure control.—Buckeye automatic change cock.—Auxiliary hydraulic equipment.

In discussing the manipulation of the formers and presses and the cake packers, little reference has been made to the important matter of hydraulic operation. As now practically perfected, the hydraulic system involves one or more pumps, at least two accumulators with automatic controlling valves and devices, and an automatic change cock fitted to each press. The working fluid used for the transmission of the pressure is linseed oil, both on account of its low freezing point and because of its slight effect on pipes and valves, but principally because of the fact that any leakage through press-ram packings thus results in no detriment to the oil product from the presses. A supply tank is provided in connection with the pump, from which the pump draws its working fluid, and the returns from presses, formers, and cake packers are piped to this tank. The pump may be either direct steam-driven, having its own steam cylinder, or belt-driven from the line shaft. The belt-driven pump is more economical of power, excepting when exhaust steam is needed for heating feed water, for warming buildings, for jacketing the heaters, or for boiling and refining oil. Pumps may be either single-pressure or double-pressure. The former style of pump is more generally used, the latter being employed usually in very small mills where a single pump only is used. This style of pump has two hydraulic cylinders, one delivering at high pressure, the other at low pressure, and each cylinder discharging into its own accumulator.

The low-pressure accumulator supplies the oil used in starting the

working stroke of the press, and also that employed for operating the former and the cake packer. The high-pressure accumulator is used only for completing the operation of the press. The pressures used are respectively about 600 and 3800 pounds per square inch. The successive automatic application of the two pressures to the press is now almost universally controlled and regulated by the automatic change cock equipment. Included in this equipment are the chokers, placed in the discharge pipes from the accumulators and serving to regulate the flow of oil to the change cock. The latter controls the admission and escape of the working fluid to and from the press cylinder. By manipulation of the valve handles, the ram may be either sent up or let down, at will. On the up-stroke, the change cock shuts off the flow of low-pressure fluid and admits the high-pressure fluid at some predetermined point of the stroke, the shifting of pressures being entirely automatic.

In early types of hydraulic equipment with only a single pressure, the necessity for control of the application of the pressure was met by providing for a reduction of the flow of fluid when the oil began to flow from the meal. This resulted in a decrease in the speed of the press at a fixed point of its upward movement, but ignored the principle of hydraulic operation that the lowest practicable pressure is always most economical. The cost of hydraulic compression varies directly as the intensity of pressure, while the speed of hydraulic operation varies inversely as the intensity of pressure. During the earlier portion of the press stroke comparatively little pressure is required to produce a considerable compression, flattening out the cakes, squaring up the plates, and finally causing the oil to start flowing. After this the resistance to compression is too great for the low-pressure fluid to overcome, and the high pressure is consequently applied. The application of the lower pressure during the earlier part of the stroke results, however, in a decreased power consumption, a quicker movement, due to the greater volume of low-pressure displacement with a given power consumption, and a reduced first cost of equipment. If the comparatively rapid movement due to the low pressure were carried too far, it would result in excessive strain on and increased breakage of the press cloth, as well as spreading of the cakes and squeezing of the meal beyond the edges of the mats. In ordinary practice the low pressure is discontinued at about the time the oil begins to flow freely; but this rule is em-

pirical only, and best practice would be based upon observation of the behavior of the cakes and press cloths. The early rapid movement of the press is of additional importance as reducing the time for preliminary compression and increasing the time for the application of full pressure, thus tending toward a maximum yield of oil and a minimum cost of operation.

Belt-driven hydraulic pumps usually operate continuously during the working time of the mill, regulation being secured by by-passing the fluid back to the supply tank when the supply of fluid is in excess of the requirements. With steam-driven pumps, regulation is by means of a chronometer throttling valve on the steam pipe. The superior economy of the power pump has led to its more general use in oil-mill operation. The supply tank for the pumps should be located so that its bottom is at least two feet above the level of the plungers. The suction pipe should be as short and straight as possible, and must be absolutely tight, else the leakage of air will impair the pump's capacity and result in the presence of foam in the compressed fluid and the rapid destruction of packing leathers. All oil entering the tank should be strained; not only new oil supplied but return oil from the presses, etc. The straining is usually done by nailing wire cloth of about No. 20 mesh to a wooden frame which is laid loosely on top of the tanks, under the oil pipes. This framed screen is thus readily removable for cleaning by a steam jet when it becomes gummed or clogged. Strainer, tank, and pipes should be thoroughly enclosed by wooden boxing to prevent the dropping of foreign matter into the working fluid.

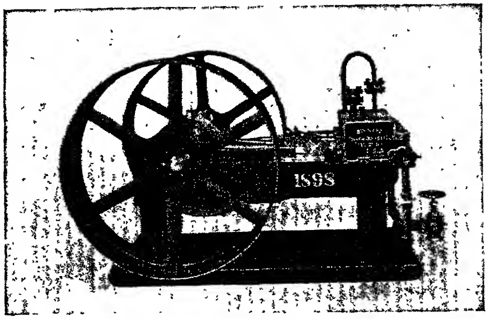


Fig. 27. — Buckeye Four-Crank Hydraulic Pump.

Fig. 27 illustrates the Buckeye four-crank hydraulic pump, a type ordinarily used in oil mills. The regulation of the pressure is as follows: when there is no demand for fluid, the plungers work idly, simply circulating the oil through and back into the supply tank, the only power consumed being that due to the friction of the pump mechanism. This

by-passing of the fluid is accomplished by means of automatic movement of a valve from a system of adjustable rods and levers at the accumulator. When working fluid is again in demand, the descent of the accumulator automatically closes the by-pass valve and the pump again delivers fluid at full working pressure. Where the pump is used on the old direct-pressure system, without accumulators, the plungers work idly when the press is let down, the low-pressure plunger sending its oil directly back to the supply tank, and the high-pressure plunger pumping its oil to the change cock at the press, thence through the open by-pass and back to the tank. When the press is to be sent up, the attendant, by closing the change cock by-pass and pulling a cord to release a trip holding open the low-pressure direct outlet at the pump, sets both plungers into action in delivering oil to the press. When the press resistance increases to such a point as to overcome the low pressure, the latter is automatically thrown out of action by opening the outlet, back to the supply tank; a check valve between the plungers closes at once, and the high-pressure plunger continues the operation alone finishing the working stroke of the press. When the low pressure is cut out, its outlet valve is tripped open, so that when the change cock by-pass is opened to let the press down, the cycle is complête, ready for the starting of another press stroke.

The crank shaft of this pump is cut from a solid wrought-iron forging. Cranks are placed 90 degrees apart. Driving pulleys are without hubs, but have dished centers, bolted male and female to flanges on the end of the crank shaft. Belts are brought to both pulleys, for twin driving, from a power source located in any convenient relative position.

Connecting rods are of steel, and are long in proportion to the stroke. The crank-pin connection is made by a phosphor-bronze yoke, adjustable and self-oiling. The crosshead end connection is designed so that a single set screw, with lock nut, provides for adjustment and also for easy disconnection. By backing off the screw, the crosshead connection is broken and the rod may be swung up to allow free withdrawal of the crosshead and plunger. Since all delivery strokes are thrust strokes, the connecting-rod end simply bears directly against the phosphor-bronze crosshead, and the set-screw connection does no work other than to draw the plunger out on its suction stroke.

Plungers are of steel, screwed into the crossheads. Valves and valve seats are of crucible steel; valve plugs and stuffing-box parts are of steel,

the latter notched for spanner-wrench adjustment. Low-pressure chambers or "check blocks" are of phosphor-bronze, while the high-pressure blocks between them are machined from solid steel forgings.

When used in connection with the two-pressure accumulator system, as is ordinarily the case, twin suction pipes are led to the outer or low-pressure chambers, whence the low-pressure accumulator is supplied. The high-pressure chambers draw upon the low-pressure system for their supply of oil for delivery to the high-pressure accumulator. When the pump is working idly, all plungers simply circulate their oil from the supply tank to the controlling mechanism at the accumulators and thence back to the tank. The pump is mounted on a base plate, the edges of which are flanged to form a drip pan to catch whatever leakage may occur. The plungers are packed with cup leather or crimp packings. The dies for forming these cup leathers are made in two pieces, male and female, with suitable bolts for drawing them together. Only flawless castings machined accurately in the lathe should be used. Much of the success of hydraulic operation depends upon the tightness and endurance of the packings. A full set of tools for regrinding pump valves, and a few spare valves, should be kept on hand. The type of pump illustrated in Fig. 27 is made in two sizes. The smaller occupies a floor space of 6 feet 2¼ inches by 4 feet, stands 4 feet 2 inches above the floor, runs at 40 to 50 r.p.m., and weighs 3140 pounds. The larger, which weighs 4220 pounds, runs at 30 to 40 r.p.m., stands 4 feet 5 inches above the floor, and occupies a space of 6 feet 3 inches by 4 feet 11 inches.

It is customary to allow one hydraulic pump for from three to six presses; say from one to two pumps per set of six presses. The necessary capacities of pumps may be reduced, in large mills, by avoiding the working of all of the sets of presses to the same schedule, a five-minute interval being desirable for this purpose. The complication of operation in other respects leads, however, to a general disregard of this minor economy. A pump of the type illustrated in Fig. 27 costs approximately $1000.

The accumulator, as an element in the hydraulic system, has several objects. It stores the hydraulic fluid, which is, of course, intermittently used. It thus produces a steadier load on the pumps than would otherwise be possible. It steadies the pressure, reducing shocks and sudden impulses which would damage the machinery and the pipe lines. It

acts as a regulating valve, making the pressure absolutely uniform while any pressure exists.

The accumulator consists essentially of a vertical sheet-iron cylinder, filled with hammer scale or other cheap, heavy material, superimposed upon a ram, to which it is firmly attached. A stout framework guides the apparatus in its upward and downward movement. The ram

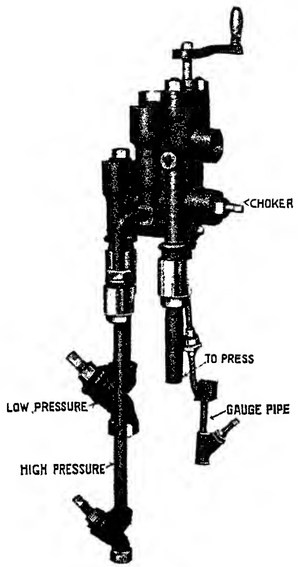


FIG. 27b. — SMITH-VAILE AUTOMATIC CHANGE VALVE.

travels vertically in an hydraulic cylinder, firmly supported on solid foundations. As working fluid is admitted to this cylinder, the ram and weighted superstructure rise to the height permitted, thus storing the fluid in quantities corresponding with the ram displacement. Sometimes, instead of by a hollow cylinder filled with scrap material, the necessary weight is provided by heavy disk-shaped castings which fit over the ram. The pipe connections to the accumulator cylinder are always open when the mill is in operation, but valves should be provided on these connections to permit of their being cut out for repairs, whenever more than one accumulator is used on a single-pressure system. An automatic by-pass valve is provided, which cuts off the accumulator from the system of supply piping whenever the former reaches its highest permissible position, and shunts the oil from the pump

back to the supply tank. When the accumulator falls, by reason of the drawing off of fluid to the presses, to a predetermined lower point, the supply line from the pump is again opened and the by-pass to the supply tank automatically cut off. Besides this by-pass and relief valve, an ordinary safety valve is provided. This is set at a pressure slightly higher than that fixed upon the system by the weight of the accumulator. In case of a failure of the by-pass valve to operate, the safety valve then prevents breakdown due to the uncontrolled pressure which might be imposed by the pumps upon the weighted cylinder and the housing which supports it.

Compressed-air accumulators, now seldom seen, utilize the compression of air in a closed cylinder to give storage of hydraulic energy, instead of the dead weight of a mass of metal. The air is compressed by

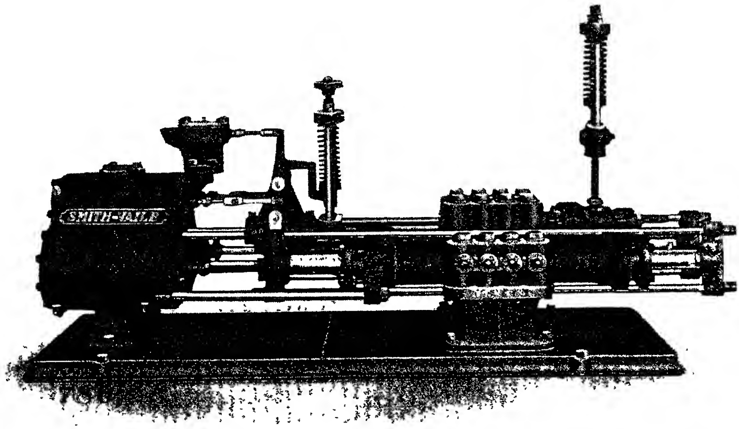


FIG. 27c. — DUPLEX HYDRAULIC PUMP.

causing the working fluid to flow into this cylinder, which is immovable. The principle of operation is precisely the same as that of the "dead-weight" accumulator.

The size of ram and the weight of the accumulator determine the constant pressure upon the hydraulic system. Thus, for 4000 pounds pressure per square inch, a 20-ton accumulator would have a ram area of $2000 \times 20 \div 4000 = 10$ square inches, or a diameter of 3.57 inches. If the ram diameter, for an accumulator of this weight, were 10 inches, its area would be 78.5 square inches, and the pressure per square inch

acts as a regulating valve, making the pressure absolutely uniform while any pressure exists.

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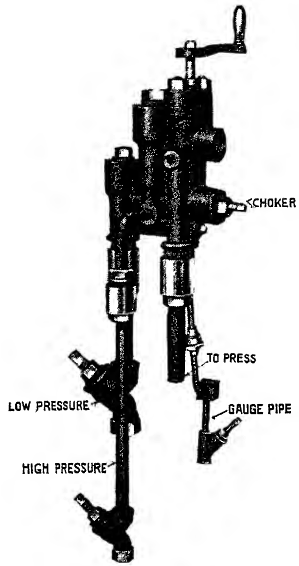


FIG. 27b. — SMITH-VAILE AUTOMATIC CHANGE VALVE.

travels vertically in an hydraulic cylinder, firmly supported on solid foundations. As working fluid is admitted to this cylinder, the ram and weighted superstructure rise to the height permitted, thus storing the fluid in quantities corresponding with the ram displacement. Sometimes, instead of by a hollow cylinder filled with scrap material, the necessary weight is provided by heavy disk-shaped castings which fit over the ram. The pipe connections to the accumulator cylinder are always open when the mill is in operation, but valves should be provided on these connections to permit of their being cut out for repairs, whenever more than one accumulator is used on a single-pressure system. An automatic by-pass valve is provided, which cuts off the accumulator from the system of supply piping whenever the former reaches its highest permissible position, and shunts the oil from the pump

back to the supply tank. When the accumulator falls, by reason of the drawing off of fluid to the presses, to a predetermined lower point, the supply line from the pump is again opened and the by-pass to the supply tank automatically cut off. Besides this by-pass and relief valve, an ordinary safety valve is provided. This is set at a pressure slightly higher than that fixed upon the system by the weight of the accumulator. In case of a failure of the by-pass valve to operate, the safety valve then prevents breakdown due to the uncontrolled pressure which might be imposed by the pumps upon the weighted cylinder and the housing which supports it.

Compressed-air accumulators, now seldom seen, utilize the compression of air in a closed cylinder to give storage of hydraulic energy, instead of the dead weight of a mass of metal. The air is compressed by

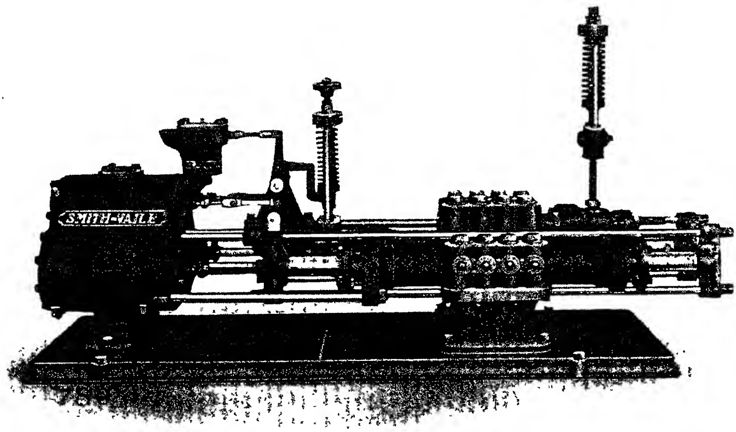


FIG. 27c. — DUPLEX HYDRAULIC PUMP.

causing the working fluid to flow into this cylinder, which is immovable. The principle of operation is precisely the same as that of the "dead-weight" accumulator.

The size of ram and the weight of the accumulator determine the constant pressure upon the hydraulic system. Thus, for 4000 pounds pressure per square inch, a 20-ton accumulator would have a ram area of $2000 \times 20 \div 4000 = 10$ square inches, or a diameter of 3.57 inches. If the ram diameter, for an accumulator of this weight, were 10 inches, its area would be 78.5 square inches, and the pressure per square inch

which it would produce would be $2000 \times 20 \div 78.5 = 510$ pounds. Where pumps are steam-driven, the ratios of steam and hydraulic cylinders must always be so adjusted to the respective pressures that the steam end will be capable of exerting some excess in total pressure over that against which it operates. For example, if the hydraulic pressure is 4000 pounds per square inch, the steam pressure 100 pounds, and the hydraulic cylinder has a diameter of $1\frac{1}{2}$ inches, giving an area of 1.77 square inches, the area of the steam cylinder must be at least $\frac{4000}{100} \times 1.77 = 70.8$ square inches, or its diameter must exceed $9\frac{1}{2}$ inches, else it will absolutely fail to operate. In practice, the diameter would have to be greater than this to cover losses due to slip and leakage and an occasional reduction of steam pressure.

Fig. 29 represents a pair of high and low pressure accumulators of the "dead-weight" type, complete with base plates and housings, and with the regulating and operative equipment shown in detail. When a steam hydraulic pump is used, with a chronometer or balanced valve, as already described, this valve does not throttle or choke the supply of steam to the pump, but by reason of being balanced, completely opens or closes immediately when the accumulator has reached the desired point on either up or down stroke.

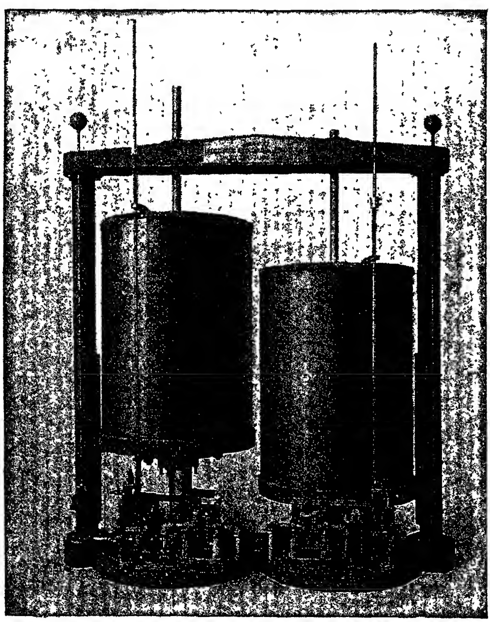


FIG. 29. — HYDRAULIC ACCUMULATORS.

When the accumulators are in use and working properly, the weight tanks are constantly in flotation; in fact, whenever a weight tank settles upon its bumper blocks, such action should be taken as positive indication of a leak somewhere, and this leak should be located and stopped at once. By piping the outlets from all relief valves sepa-

rately to the pump tank, leakages may the more readily be detected and located. In this feature of leakage indication lies one valuable point of advantage for the accumulator system.

By adoption of the "inverted construction," with plungers stationary, the weight of the heavy cylinders themselves becomes useful as ballast. The remainder of the necessary weight is made up by loading the ballast tanks with a cheap and compact filling. The low-pressure and high-pressure accumulators are absolutely independent of each other in operation. Each has its own controlling mechanism, and is complete in itself.

In the Buckeye system, the rams or plungers are hollow, and through them the working fluid reaches the accumulators. The low-pressure cylinder illustrated is of cast iron; the high-pressure is of steel tubing encased in a jacket of cast iron. They are tested respectively to pressures of 600 and 5000 pounds per square inch. Three regular sizes are built, 6-ton, 12-ton, and 20-ton. The 20-ton set is commonly used, the 12-ton being employed for small mills. Few mills use more than one set of accumulators, probably not over two or three mills in the country having two or more sets. Of necessity, therefore, the hydraulic systems are non-separable into groups corresponding with the press grouping. The leading dimensions of the double sets of accumulators of the nominal capacities given are as follows:

Size.		Six-Ton.	Twelve-Ton.	Twenty-Ton.
Floor space	Breadth	8 ft. 8 in.	11 ft. 0 in.	13 ft. 3 in.
	Depth	3 ft. 8 in.	4 ft. 10 in.	5 ft. 10 in.
Height		9 ft. 6 in.	11 ft. 3 in.	13 ft. 8 in.
Weights	Machine only	10,100 lbs.	13,600 lbs.	22,100 lbs.
	Ballast	19,100 lbs.	42,200 lbs.	67,000 lbs.
	Total	29,200 lbs.	55,800 lbs.	89,100 lbs.

A set of the twenty-ton accumulators, complete, costs upward of \$2500. Fig. 29a shows the control-valve piping connections.

The most vital feature of two-pressure hydraulic operation is the automatic change cock. The two pressures, automatically controlled, give initial rapidity and final intensity of pressure application. Both pressures are under perfect control, the lower one first raising the ram

at any speed for which the apparatus may be set, and the high pressure coming automatically and gradually into play for the completion of the stroke. The full high pressure is finally exerted upon the ram only after the press has reached very nearly its upward limit of travel. After charging the press, the pressman simply reverses the operating valves, closing the outlet and opening the inlet. He then pays no further attention to the press until it is time to let it down at the close of the pressing

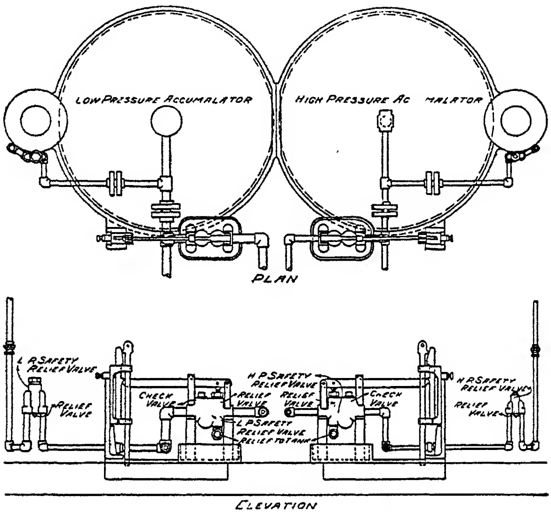


FIG. 29a. — ACCUMULATOR CONTROLLING VALVES AND PIPING.

interval. The result of this gradual change in pressure is a reduced consumption of press cloth, maximum output, maximum yield of oil, and reduced consumption of hydraulic power. The old type of "change block," consisting of a nest of valves controlling each one of a group of presses, left too much at the mercy of the pressman. For a group of six presses, there were eighteen valves in a single block, comprising the high-pressure, low-pressure, and discharge valves for each press. They were necessarily inconveniently located with respect to some of the presses. It was easy to make a mistake, opening or closing the wrong valve; still easier to forget, leaving two valves open which should never be open together, or anticipating or delaying the change from low to high pressure, with consequent detrimental effects of one kind or

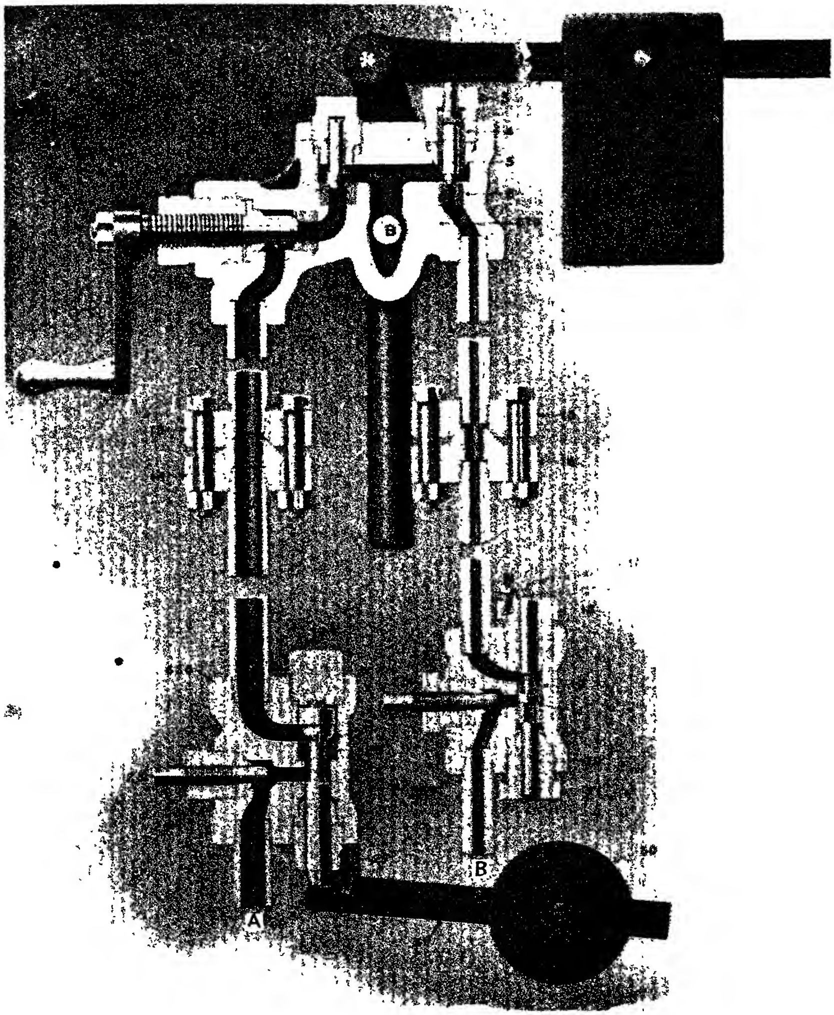


FIG. 31.—DETAILS OF FRENCH AUTOMATIC CHANGE VALVE.

another. Operation was practically never correct with this system, and it is rightfully now generally abandoned.

Fig. 31 shows the automatic change valve made by the French Oil Mill Machinery Company. This sends the press up very quickly to the point where the oil first leaves the meal, at a pressure of about 250 pounds per square inch on the ram. The speed of the press is then instantaneously

checked to below two inches per minute for the remaining distance, and the high-pressure fluid is not admitted until the low-pressure has reached the limit of its usefulness, at from 450 to 700 pounds intensity. The throttling of the low pressure after reaching 250 pounds checks the creeping or spreading of the cake, which is responsible for increased cost of press cloth and decreased yields of oil. The steady increase of pressure liberates the oil slowly at the start, permitting the relatively soft cake to set without straining the press cloth; and the final high-pressure application is reached about as soon as with hand regulation. The high pressure is controlled by a self-closing choker. The checking of the application of low pressure may be adjusted to take place at any desired point. The high-pressure choker is provided with a flushing connection for instantaneously clearing it out when it becomes clogged, without interference with the press action. After flushing, the valve is instantaneously and automatically returned to its former position. High and low pressure cut-offs, checks, and unions form parts of the valve. The valves are tested to 5000 pounds pressure.

Referring to the details of Fig. 31, the low-pressure admission is at *A*, the high-pressure at *B*. The discharge plug 11 controls the movement of the fluid to the press or from the press to the return line. 8 is a check valve closing off the low-pressure system from the press when the pressure in the latter exceeds that in the former. 5 is the automatic change valve proper, involving a check valve also, which is held upon its seat by the lever and weight until the low-pressure fluid, acting on the under side, opens the valve and admits the high-pressure. A shut-off plug is placed in the low-pressure automatic speed regulator, so that the pressure may be entirely cut off. The plunger *H* is held from its seat by the small lever 31 and weight, allowing, ordinarily, a free passage of fluid through the valve. When the press pressure reaches a predetermined point, the pressure on the upper surface of the plunger *H* forces it upon its seat and cuts off all fluid excepting such as can flow through the small groove. The top of the plunger forms a dashpot, which ensures smooth working.

The high-pressure choker also has a shut-off plug. The stem *L* is constantly held against its seat by the fluid pressure. This allows the high-pressure fluid to flow through the groove only. Should this groove become clogged, the projecting end of the stem is pressed down by inserting the small lever under *N*, when the obstruction is

washed past the seat. The stem immediately returns to its seat when the lever is withdrawn.

The higher the intensity of pressure in the low-pressure system, the later the high pressure may be admitted. This change in the point of high-pressure admission is obtained by moving the larger weight on the lever. The regulation of the low pressure is effected by moving the weight on lever 31.

Interesting information is presented by the curves of Fig. 32. These curves are stated to be based upon the results of actual measurement.

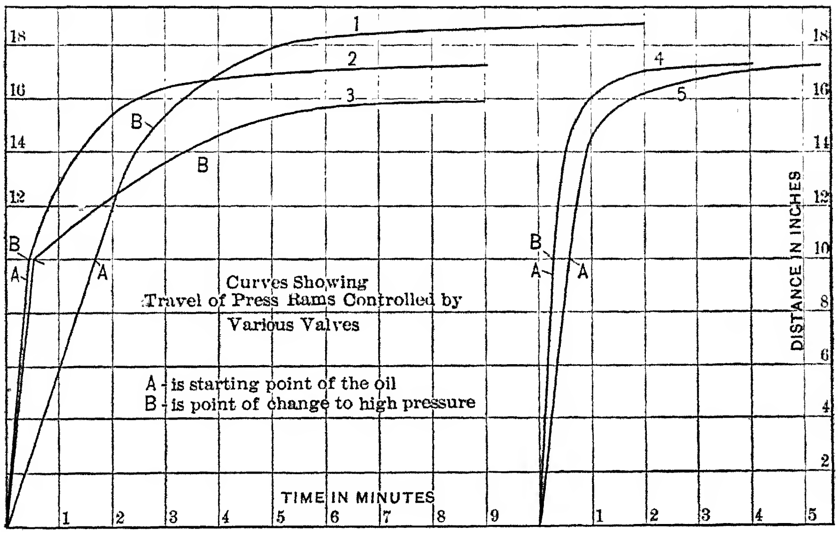


FIG. 32.

They show the ram movements, in inches, during successive intervals after the application of the pressure, for different control valves, curve 3 representing the action of the French automatic valve. Curve 4 is from the same type of valve as curve 2, but evidences defective operation, due to the pressman's having left the high-pressure choker wide open to avoid clogging. Curve 5 is from a non-automatic valve with no low-pressure choker and an extremely small choker on the high pressure. Curves 1 to 3 may be considered as typical valves well operated. From the five curves the table on following page is drawn.

Number of Curve.	Speed per Minute up to the Beginning of the Flow of Oil.	Maximum Speed after Oil begins to flow.	Total Travel of the Ram while under High Pressure.	Theoretical Horsepower used in Pressing.
1	6 in.	6 in.	4 in.	.60
2	24 in.	$4\frac{1}{2}$ in.	$7\frac{1}{4}$ in.	1.14
3	22 in.	$1\frac{1}{2}$ in.	$2\frac{1}{2}$ in.	.58
4	38 in.	38 in.	$7\frac{1}{4}$ in.	2.52
5	20 in.	17 in.	$7\frac{1}{4}$ in.	1.91

The last column of this table is calculated on the assumption that the pressures used are 500 and 4000 pounds per square inch, the rams being 16 inches in diameter. Thus, for curve 1, the ram diameter being 16 inches, its area is 201 square inches, and the total low pressure is $201 \times 500 = 100{,}500$ pounds, or the total high pressure is $201 \times 4000 = 804{,}000$ pounds. The low pressure is applied for 2.7 minutes (up to point B), during which the ram rises 15.2 inches. The power absorbed in this amount of ram travel is $100{,}500 \times 15.2$ inch-pounds, or 127,000 foot-pounds. This amount of power being applied in 2.7 minutes, the power per minute is $127{,}000 \div 2.7 = 47{,}000$ foot-pounds, or 1.43 horsepower. The high pressure is applied for 9.3 minutes, and produces a movement of 4 inches, absorbing $804{,}000 \times 4 = 3{,}216{,}000$ inch-pounds or 268,000 foot-pounds, or 28,900 foot-pounds per minute, or .877 horsepower. The total horsepower used during the stroke of the press is $\{(1.43 \times 2.7) + (.877 \times 9.3)\} \div 12.0 = 1.00$, and if the average interval between pressings was 20 minutes, the average power consumption continuously was theoretically $\frac{12}{20} \times 1.00 = .60$ horsepower. Curve 3 is that which gives the lowest consumption of power. Curves 4 and 5 are particularly bad, the rapid application of the pressure resulting in reduced yield due to spreading of cake, and enormous waste of press cloth.

The parts of the Buckeye automatic change cock are shown in Fig. 33. Each press has one of these cocks and is controlled independently of the other presses. Supply pipes from the low-pressure and high-pressure accumulators are brought to the under side of the cocks, a short distance beneath which are inserted the chokers, one to each pipe. These chokers regulate the speed of the press by throttling the flow of fluid. After passing the choker, the change cock, and the entrance to

the ram cylinder, the fluid is subjected only to such pressure as is caused by the resistance to the upward travel of the ram. The high-pressure fluid is held back by an upper valve, pressed to its seat by a weighted lever. The application of the low-pressure fluid continues until the resistance of the ram causes the pressure to rise to such a point as to lift the weighted valve and allow entrance of the high-pressure fluid. The latter then comes into play, its application being rendered gradual by the action of the choker on the high-pressure pipe.

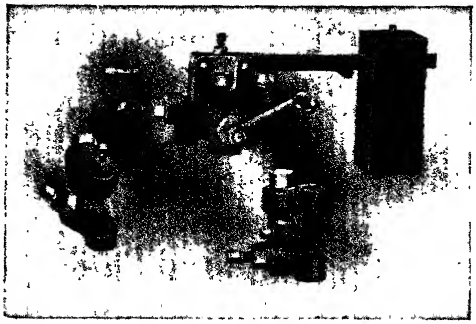


FIG. 33.—AUTOMATIC CHANGE COCK AND CHOKERS.

Immediately upon opening the weighted valve, the high-pressure oil closes the low-pressure choker check valve and throws the low-pressure system entirely out of connection with the press. When the press is let down by closing the inlet valve and opening the outlet valve, the pressure is relieved from the weighted valve, and the latter returns to its seat. Thus the high-pressure system is shut off and held back until required for the next pressing. The body castings of this valve are of phosphor-bronze, with valves and seats of crucible steel. A guard screw is placed above the choker disks, as shown in Fig. 33, protecting the aperture therein from obstruction by foreign material in the fluid, and providing for the removal of such obstruction by forcing it to and through the opening. The outlet valve, the weighted top valve of the change cock, and the check valve of the low-pressure choker must be kept absolutely tight if good results are to be secured. The outlet valve is more likely to leak than any other part of the hydraulic system. This is made large in order that the presses may descend quickly, and should be closed very tight when the pressure is to be applied; otherwise the forcing of minute particles of oil through at high velocities will inevitably cut the seat. Fig. 34 gives views of the detail of piping at the change cock.

Various auxiliary equipment used in connection with the hydraulic system may be briefly mentioned, including the hydraulic pressure

gauge for attachment to each press; the hydraulic safety valve, with packed stem, phosphor bronze body, and crucible steel valves and seats; the direct-pressure change cock for controlling the operation of presses worked without accumulators by automatically changing from low pressure to high pressure at the pump; and the balanced steam valve for control of steam pumps, already referred to. Various types of hydraulic fittings are made in phosphor-bronze and cast steel. The

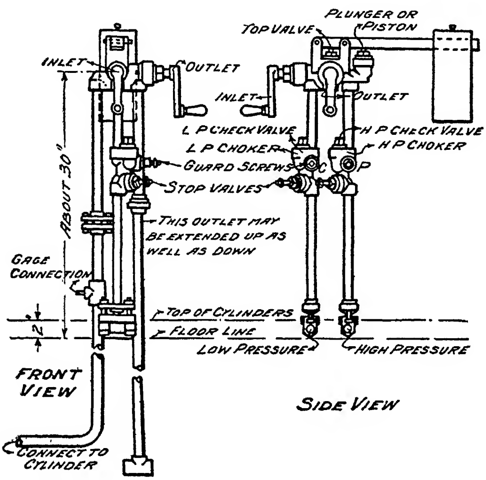


FIG. 34. — PIPING OF CHANGE COCK AND CHOKERS.

Nason Manufacturing Company of New York makes a good grade of forged-steel hydraulic fittings for the smaller sizes of pipe.

Much trouble is frequently experienced with the pipe lines in putting into service any new hydraulic installation. The pipe should be double extra strong, with forged or cast-steel fittings of heaviest weight, and all stops and checks should be the product of manufacturers who make a specialty of this class of work. Only lap-welded or seamless drawn pipe should be used. The smaller fittings and flanges should be forged steel. Flanged joints should be made by screwing the pipe through the flange in a machine and refacing pipe and flange together in the lathe. The flanges should be tongued and grooved, the width of the groove not exceeding one-half inch. A leather or fiber gasket may be used, but a ground joint is best. Outside of the tongue or groove, as well as inside, the flanges should not meet, a distance of

one-thirty-second to one-sixteenth inch being left, so that all the strain imposed by the bolts will be applied at the tongued and grooved joint. The flanges must be back-faced or spot-faced.

There will always be more or less grit, dirt, pipe scale, and chips from threads in the pipe lines, and these must be gradually strained out and completely eliminated before such difficulties as the cutting of valve seats, resulting from these causes, can be completely overcome.

CHAPTER VII.

THE TREATMENT OF THE OIL FROM THE PRESS TO THE CONSUMER.

Necessity for clarifying the oil.—Methods of clarifying.—Troughs.—Arrangement of receiving tanks.—Influence of temperature.—Special forms of receiving tanks and troughs.—The filter press.—Operation of filtering.—A complete filtering plant.—The filter cloths.—Advantages of slow filtration.—Pumps and pump control.—Capacity of filter presses.—Foots.—Storage of oil.—Tanks.—Piping.—Filling-room arrangement.—Automatic barrel fillers.—Filling-room details.—Methods of shipping oil.—Tank wagons.—The barrel.—Commercial conditions.—Cost of barreling oil.—Tank stations.—Size of barrel, shape of barrel.—Empty barrel storage.—Preparation of second-hand barrels.—Painting.—Stenciling.—Differences in tare weight.—Effect of heat on cooperage.—Drums.—The oil-tank car.—Its advantages.—Importance of raw oil as the crusher's principal product.

The warm amber-colored fluid flowing from the backs of the presses is not yet the raw[1] linseed oil of commerce. To some slight extent this crude unfiltered material is used, principally for manufacturing soap; but in general the oil must be clarified by cooling, filtration, and settling before it is ready for the market. These are operations which involve essentially the lapse of a considerable period of time. In the early history of the industry we find evidences that clarifying was performed as the result solely of undisturbed settling in tanks, without the introduction of any mechanical agents whatever; but this process has been found to be too slow. This is rather unfortunate, since it is the nature of linseed oil to continue to deposit sediment almost indefinitely, and long-continued tank storage will remove a considerable quantity of particles even after the most improved filtering machinery has been used.

Modern practice consists in slowly circulating the oil through troughs from the presses to receiving tanks by gravity. From the latter it is pumped to weighing tanks set upon platform scales, from which it flows by gravity or under pressure to temporary storage in

[1] Linseed oil is never described as "crude." The raw oil is for many purposes a superior oil to any of the refined products. Neither is there any such trade designation as "off." If the oil is not absolutely pure, it is not linseed oil.

the filtering department. From this temporary storage the oil is forced, as may be convenient, through the filter presses and into inside or outside storage tanks, from which it is drawn as required for shipment. Besides more or less meal in suspension, the oil contains, as it flows from the press, sediment-forming material in solution. Both classes of material must be removed as thoroughly as possible.

The troughs behind the presses, usually of wood, sometimes lined with tin, always with open tops or with covers readily removable, should be of such cross section that the velocity of flow of the oil at its maximum volume shall not exceed six inches per second. The troughs should be as long as possible, in order to give ample time for the deposit of the heaviest sediment; and in order to give this necessary length the troughs are usually doubled back and forth behind the presses, so that the oil travels a distance equal to from two to six times the length of the row of presses. Screens or perforated iron plates may be inserted at various points, or baffle boards of one form or another, the mesh of the screens decreasing as the distance from the press increases; but these devices must be so constructed and installed as to be readily removable, leaving a smooth interior surface for the troughs, in order to facilitate scraping out the deposited material about once each week. A shallow, wide trough section is best, as giving the most surface for the deposit of sediment in proportion to the volume of flow. For cleaning the troughs, a wood or smooth-edged iron scoop should be used, having a large number of perforations, through which oil may drain back into the trough while the "foots," or settled materials, are being shoveled out.

The receiving tanks should be subdivided, one being provided, if possible, for each group of presses, and each having a capacity sufficient to contain all the oil produced by such group during a twelve-hour shift; or say for six presses a capacity of 1500 gallons. This permits of measuring the oil production from each set of presses separately.

Fig. 36a shows the automatic oil scales commonly used in English mills. The oil is piped to the hopper. When the exact quantity to be measured has entered the scales, the flow is cut off and the basin tipped. Each discharge of the basin is recorded on the indicator. No attention is required to operate the scale. The machine is applicable to the shipping of oil, but the containers must be placed and

removed by an attendant. It is made to discharge from 22 to 224 pounds per operation, giving a capacity of from 1000 to 8500 pounds per hour.

Sometimes this advantage is foregone and the tanks arranged in series to facilitate settling. A long trough subdivided into several compartments is built above a series of tanks. Oil flows from the presses to the first compartment, and then runs around baffle boards successively through the compartments, finally falling through a pipe to the bottom of the first tank. An overflow outlet is provided near the top of this tank, connecting by means of a pipe with the bottom

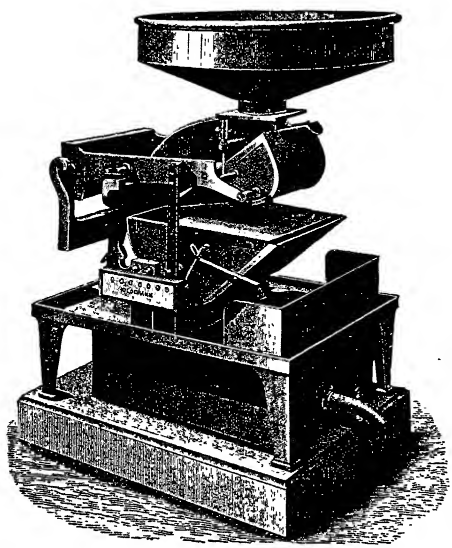


FIG. 36a. — AUTOMATIC SCALES FOR OIL.
(Rose, Downs & Thompson, Ltd.)

of the second tank, which is similarly piped to the third tank, and so on. The oil gradually rises in the various tanks in succession, and at each successive overflow the cleaner portion of the oil, only, is carried over. Most of the sediment will be deposited in the first two or three tanks, the warmth of the oil at this stage of its history assisting in its rapid, if incomplete, settlement. This is a good arrangement, but expensive. Its advantages may be combined with those of individual receiving tanks by retaining the latter and having one battery of settling tanks, as described, supplied by one main compartment

trough receiving the oil from all of the receiving tanks. The temperature of the oil during the settling process will in this case be lower, and it would probably be better to remove the entire settling equipment from the press room to the filtering department. The lower temperature of the oil thus experienced is an apparent rather than a real disadvantage. Warm oil deposits readily such foots as it apparently contains; but upon cooling, the oil again becomes cloudy, due to the precipitation of impurities formerly in solution. Warm filtration or sedimentation removes suspended matter, while cold storage precipitates and facilitates the removal of dissolved matter. Oil is apparently much more quickly clarified if treated while warm; but this clearness is delusive, and thorough filtration is possible only with cold oil. The temptation is always toward increased speed and too high a temperature during settlement and filtration.

One crusher has suggested the use of receiving tanks, located immediately behind the presses, having the shape of inverted cones, from the apex of which the foots may be drawn off in concentrated form at regular intervals, the comparatively clear oil flowing from the top. This arangement is, of course, of benefit in removing only some of the suspended matter. A more elaborate device for accomplishing the same result, which also serves to drive off some of the moisture from the oil, thus rendering it more immediately suitable for certain refining processes, is that of a steam-jacketed U-shaped sheet-iron trough, having vertical baffles over and under which the current of oil passes. The heat and the flow of liquid agitate the suspended matter which is deposited against the lower baffles.

Linseed oil fresh from the presses is edible. While it does not spoil or become rancid with age, like various other expressed oils, it does become decidedly less palatable.

The effective device for actual filtration, when worked with cold oil, is the filter press, introduced in approximately its present form about 1860. This consists of a number of recessed plates, which in operation are clamped together so as to form a chamber between each two plates. In each plate a raised boss is provided, in which an opening is drilled. The faces of these bosses and of the edges of the plates are machined off square. When the boss and hole are in the center of the plate, as is customary, the hollow chambers between the plates are obviously annular in form. A number of canvas bags of the same

size as the plates are made, each bag being stitched all around, but having a ring-reënforced hole in each side, corresponding in location to that of the hole in the boss on the plates. The cloth is placed between the plates, with its holes secured in proper position by means of flanges of suitable thickness, after which the plates are clamped together. The compartments between the plates are consequently now lined with canvas, while the holes through the bosses form a continuous tube running through all of the plates, having open communication with the interior of the canvas bags. Oil is pumped into this tube, and maintained under pressure, gradually percolating through the bags and flowing down channeled grooves on the surface of the plates to a draw-off connection at the bottom of each chamber. The pressure does not injure the canvas bags, because these have a solid backing of cast iron. Steadiness of pressure is secured by using a regulating valve on the steam pipe to the pump, arranged so that any differential increase in pressure cuts off the supply of steam, while a decrease in pressure admits steam. Sometimes the canvas bags are made of double thickness. In any case, the foots are deposited upon the inner side of the bags, and after a reasonable length of time, when the oil has ceased to flow freely, the plates are unclamped, the bags removed, and the foots scraped off by wooden paddles. The bags are then washed and dried and are ready for a further period of service. Washing is expedited by a liberal use of soda ash or naphtha. The filtering material, loosely called canvas, is cotton duck, of width suitable for stitching into bags without waste, and of weight and weave controlled largely by considerations of individual preference. It must be sufficiently strong to withstand the pressure at the joints of the plates, and must be closely woven. Paper, usually employed for the filtration of refined oil, is sometimes used for raw oil. This gives an unusually clear and brilliant product.

The oil contained in the foots which are deposited on the filter cloths may be partially removed, before dismantling the press, by turning on high-pressure steam for a few moments. Double gutters are used under the drain pipes, in some cases, to keep the press washings separate from the clear filtered oil. In case of breakage of the cloth while the filtering is going on, the drain from the compartment in question should be immediately turned off into the gutter used for press washings. For facilitating the delivery of the discharged oil to

either of the gutters at will, the switch cock shown in Fig. 39 is used. As the deposit of foots is from the bottom of the bags upward, the bosses through which the supply pipe is run are frequently located at

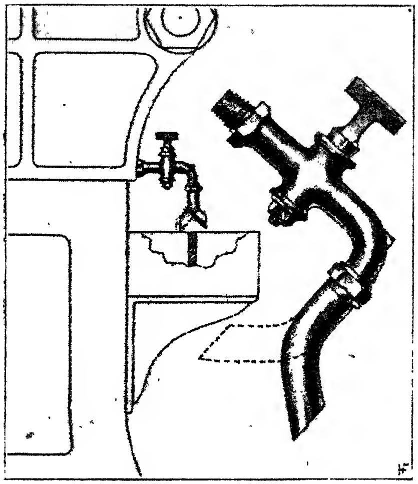


FIG. 39. — SWITCH-COCK AND DOUBLE GUTTER.

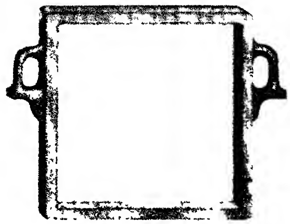


FIG. 40. — FILTER PRESS FRAME.

the tops of the plates. This increases the capacity between cleanings. The capacity of the press may also be increased by increasing the distance between the plates by means of flanges or "frames," as shown

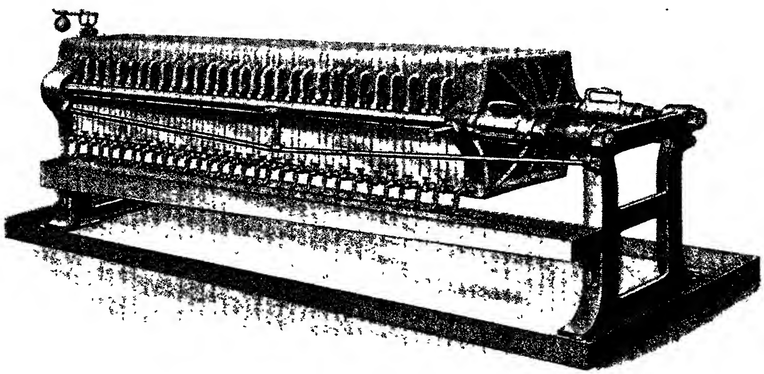


FIG. 37. — SQUARE PLATE FILTER PRESS.

in Fig. 40. When these are employed, the filter cloth is cut into single sheets, one placed on each side of the "frame," instead of being made

into bags. Fig. 37 represents a modern filter press, Fig. 38 one of the plates, having the bossed opening at the upper left-hand corner.

Fig. 37a shows some standard types of plates and frames. Fig. 38 shows the Sperry filter plate, having the opening at the upper left-hand corner and the switch cock at the lower right-hand corner.

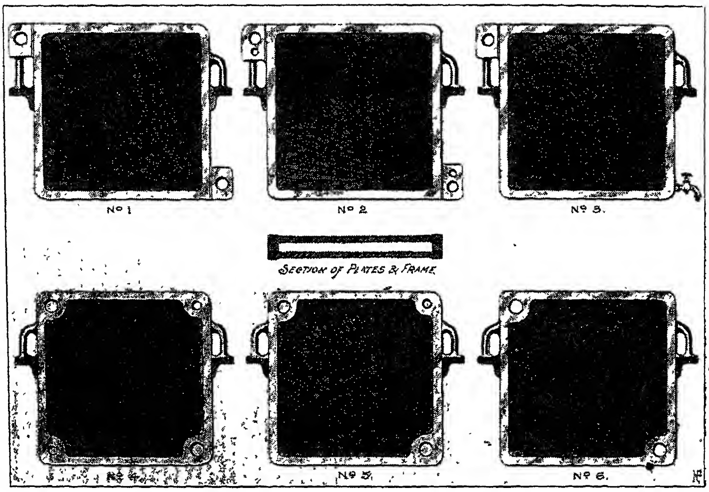


Fig. 37a. — Filter Press Details.

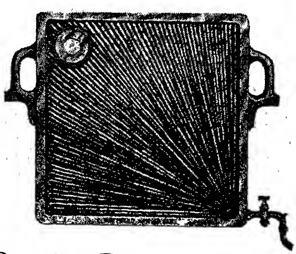


Fig. 38. — Filter Press Plate.

Wood plates are sometimes used for filter presses. The best plate is one made of metal, machined to template and interchangeable with others of the same size.

Fig. 41 shows a complete press-filtering plant. The large tank at the left, on the floor below the filter press, receives oil from the press room. From this tank oil flows by gravity to the pump, which delivers it to the filter press. A relief or safety valve is attached to this dis-

charge pipe to prevent excess of pressure. A small tee is also provided to receive a steam pipe for blowing out the press. A gauge is usually installed, and a small pipe line from the discharge, not shown in the illustration, runs to the regulating throttle valve on the steam supply to the pump. A check valve is placed on the pump discharge, so that the pressure on the press will fall off gradually only, in case of accidental stoppage of the pump. The press drains to a double gutter, the wider gutter being for filtered oil, which is carried to the large tank

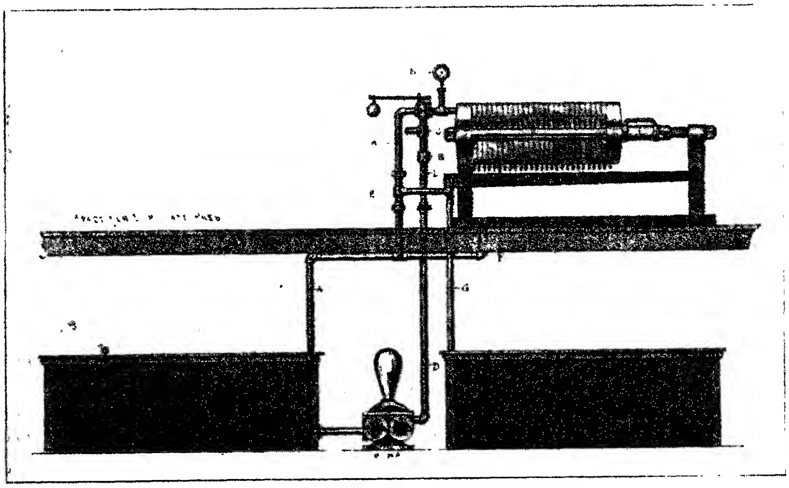


Fig. 41. — Complete Filtering Plant.

immediately below the press. The other gutter, carrying press washings, drains back into the supply oil tank at the left. The pipe F runs from the drip pan under the press back to the supply oil tank. When the accumulation of foots has progressed so far as to interrupt operation, the relief valve M opens. This may be piped back, as shown, to the supply oil tank. In good practice such an event will not occur, as the amount of filtered oil discharged will have long since been greatly reduced and the cloths consequently removed. The press is finally steamed out, the washings being returned to the supply oil tank, the nuts on the side screens loosened, and the clamps which hold up the plates taken off. The plates are shoved back, sliding on the side screws as guides (note the side lugs, Fig. 38), and the heavily caked "bags" removed.

Should the press be left out of use for several days, the cloths are likely to become dry, hard, and impervious to the passage of oil. To prevent this, the press should be filled with oil, the shut-offs on the drain pipes being closed. Some old types of filter presses have no shut-offs on the drain pipes, in which case oil may be slowly circulated through and back to the supply oil tank, or the cloths may be removed and washed free from oil, when they will not harden. Paper, occasionally used as a filtering material in preparing refined oils, when coated with foots, is thrown away. Several thicknesses are used in each compartment, and the pressure must be kept at a low point. Cotton duck filter cloths have a maximum life not exceeding six months, and an average life of probably only a small fraction of this time. They are frequently subjected to pressures up to 80 pounds or more, but 50 pounds is a better limit, and the best results are obtained by filtering at a pressure not exceeding 30 pounds, automatically regulated. The old method of setting the relief valve at high pressure, dispensing with the steam pump regulating valve, and gradually increasing the pressure of filtration, was not one adapted to give the clearest oil, and should rightfully be abandoned. The cloths, after removal from the press, are steamed, washed, and hung up to dry. When set in the press, the cloths should be carefully placed so as to form, substantially, a pair of gaskets at the plate and boss faces. If irregularly set, leakage and rapid destruction of the cloth are apt to ensue. The drain outlets should all be carefully watched during the operation of filtration, and any outlet discharging cloudy oil should immediately be cut off from the filtered oil gutter.

With slow filtering, under moderate pressure not exceeding 30 pounds, and at low temperature not exceeding 70 degrees F., the oil from the filter press is suitable for immediate marketing. Such perfect filtration is not commonly given, and many crushers depend upon a subsequent settling in the storage tanks. This has the disadvantage of resulting in the deposit of foots in the bottoms of tanks, from which they are much less readily removable than from the filter cloths. Besides this, the practice mentioned ties up a considerable amount of capital in tanks and in stored oil; but the crusher usually stores oil anyway, and the buyer usually has a prejudice in favor of oil which has been stored in tanks for some length of time, and it pleases him to think that he is getting such oil. Probably it is necessary that he

should receive tanked oil when, as often occurs, the oil is filtered while warm from the presses.

Pumps for filter presses may be either steam or belt driven, automatic regulation being provided in the latter case by setting the relief valve shown in Fig. 41 at the pressure desired. Much of the economy in power resulting from the use of the belt-driven pump is thus lost, and more efficient control is provided by means of an "unloading valve," which causes the pump to discharge back into the supply oil tank, and not against pressure, whenever the pressure differentially exceeds the prescribed limit. The capacity of the pump should be ample, so that it may move smoothly at low speed. It should be duplex, double-acting, if steam-driven, and of the triplex type if belt-driven, in order that the discharge may be free from severe pulsations. For the same reason the valves should be kept in good condition. Outside end-packed plungers are better than pistons. The pump need not be brass-lined.

The filter press plates may be either round or square and may range from 18 inches to 36 inches diameter or width. One 12-press mill operated, for its raw-oil product only, one 29-plate 32-inch press and one 34-plate 30-inch press, both with square plates. A 42-press mill making a large output of refined oils used five filter presses as follows:

Two 50-plate, 32 inches square,
Two 50-plate, 30 inches square,
One 36-plate, 30 inches square.

The capacity of the presses varies so widely with differences in the method of filtration that no general rule can be given. Most mills produce refined oils, which require exceptionally slow filtration, subsequent to the original clarifying of the raw oil, during the process of treatment. This involves filter-press capacity in excess of that necessary for the raw oil alone, smaller presses sometimes being used for the production of these special oils.

Centrifugal machines for filtering have been proposed, but are not yet in use to any great extent. In the production of some grades of refined oil they have given good results, and there is no reason why they should not be applicable to all the requirements of the crusher. They are much less expensive than filter presses.

The foots resulting from settlement and filtration present one of

the serious and annoying problems in linseed crushing. They are found in the troughs carrying the oil from the presses, in the receiving tanks, in the weigh tanks, in the filter presses, and in all the storage tanks. From all of these places they must be periodically removed, as they accumulate in enormous quantities. The direct market for them is limited. Some demand exists for foots as an ingredient in the formation of putties. They have to some extent drying qualities similar to those of linseed oil. They have been used as ingredients in cheap paints for rough outside work, mainly for painting outside storage tanks by the linseed crushers themselves. A form of slag roofing has been prepared, consisting of 12 to 15 parts of foots scraped from the filter cloths, 5 parts of red lead, and 80 to 83 parts of sand. The foots are first heated to a temperature of about 200 degrees in an ordinary tar pot or its equivalent. The red lead is then added and thoroughly incorporated with the foots, after which the temperature is run up to 300 degrees, and the sand added. The sand must be thoroughly dry, — baked if necessary. The best results are obtained by using foundry sand, i.e., spent sand from an iron foundry. This cement should not dry too quickly. If it shows a disposition to get hard in less than 24 hours, the quantity of red lead should be reduced. The material is applied like tar or asphalt.

Foots from the settling troughs back of the presses contain from 80 to 90 per cent of oil, unless drained through perforated shovels, which reduces the percentage. Tank bottoms, as ordinarily cleaned out, contain 60 to 70 per cent of oil, filter-cloth scrapings rather less.[1] The surplus, over and above what can be profitably marketed, must be worked up again through the mill. As taken from troughs or tanks, the foots should be stood in barrels. Within a day or two the oil will rise to the surface and may be baled off. The residual pasty brown mass is introduced into the heaters very gradually, going thence through the mill. A massed lump of foots in the heater will spoil the oil-yielding properties of the meal to ten times the extent of its value, will damage the appearance and quality of the cake, and will be in general an unmitigated nuisance. Unless some of the foots, at least, are marketed, the mill is likely to become "choked up" with this

[1] This refers to scrapings from cloths which have been used in filtering raw oil. Cloth-scraped "boiled-oil foots," or "refinery foots," are too heavily charged with other substances to be legitimately sold as linseed oil.

refractory material, since passing it back through the heaters only partially disposes of it, the cake and oil both having a limited capacity only for its absorption. Modern methods of crushing, involving the heating of the seed, have greatly increased the production of foots, this being probably a direct result of the more thorough breaking up and separation of the oil cells in the seed. Foots are therefore a necessary evil, inseparable from augmented yields of oil.[1] The common clumsy method of disposing of them by dumping a bucketful at a time into the top of the heater, is dangerous, for the reasons above stated, as well as being costly in labor. The best method is to have a foots tank, communicating, by means of screw conveyors, with the conveyor carrying ground seed from the rolls to the heaters. In this way the admixture of foots may be perfectly regulated, the tempering can be adjusted to suit the percentage of foots worked, and the action of the conveyor thoroughly mixes foots and meal, preventing the formation of sticky balls of concentrated foots. It would probably be best in the long run if all of the foots, after having the oil floated off, could be sold, even at a loss; but crushers cannot see their way clear to do this, and the customer consequently often gets the foots in the forms of oil or cake.

The filtered oil from the filter presses, if not required for immediate marketing, is pumped to the storage tanks. The amount of oil storage necessary for a mill depends upon speculative and commercial considerations. Disregarding the question of cost of tanks, the more storage the better, since it enables the crusher to continue in operation even when the oil market is unfavorable, or to shut down his mill when fuel or labor difficulties make such a course necessary, without risking the loss of his trade. Ten large crushers having an aggregate capacity of 35,000 bushels of seed daily have inside oil tank storage capacities aggregating 3,000,000 gallons, with outside storage capacities totaling 4,300,000 gallons. The total storage facilities would therefore take care of nearly 86 days' output. This is probably not far from the average ratio, and is admittedly too low. Ample storage is most vital to profitable operation. The inside tankage in the above case averages rather higher in proportion to the total than is usually

[1] Even a small mill will accumulate from 6 to 8 barrels of foots per week, exclusive of "tank-bottoms." A large mill may have 50 barrels or more to dispose of in an equal period.

considered necessary. Crushers prefer to store their refined oils, and raw oil intended for immediate shipment, indoors and in warm rooms, thus keeping them clear and free from sediment, in which condition they may be expected to reach the consumer. If the oil were filtered cold, however, it would remain clear at any temperature not lower than that of filtration.

Storage as an auxiliary method of clarifying oil involves the provision of ample settling surface, i.e., low, large tanks, the supply of air, the exclusion of dust, the lowest possible temperature, and occasionally an emptying of the contents of the tank to permit of the thorough removal of the foots. Riveted steel tanks are universally used.

Whenever oil flows into tanks there is a possibility of loss due to the overflowing of the tank from the carelessness of some attendant. Overflow pipes to some central tank at low elevation and under constant observation would prevent such losses; or the combination of a float with a signal gong or an alarm whistle operated by steam or compressed air, is an equal safeguard, and should not be omitted at important points. Some similar device may be advantageously used when loading tank cars.

For shipping, the oil is conducted from each storage tank by means, usually, of underground pipes, to the filling room. Each tank should be provided with a gate valve or cock, immediately at its outlet, arranged with a lock, the key being kept by the foreman of the filling room or other responsible employee. The only objection to running the pipes underground is that in time they may be expected to manifest defects, when they are comparatively inaccessible for repairs. Underground connections are frequently necessary, however, to permit of gravity flow, at all times, from storage tanks to filling room. The piping is of standard-weight wrought iron, usually with screwed joints, standard-weight gate valves or cocks, and cast-iron fittings. These specifications may properly apply to all of the oil piping about the mill. At the filling room, the pipes are carried around the sides at an elevation of three feet or more, with frequent taps off for drawing out the oil. These taps consist of a tee, looking upward, placed on the main, a short nipple, an elbow looking out, and an end of pipe about five feet long, on which is set a quick-opening lever-handled gate valve. This end of pipe is free to swing about the nipple as an axis, per-

mitting of some adjustment in its position to suit the location of the bung on the barrel, cask, or drum to be filled. It terminates in a reducing elbow, to which a short nipple, sufficiently small to be inserted in a bunghole, is screwed. The swinging pipe should be of 3-inch size, and the mains around the room and from the storage tanks should be 3 or 4 inch. Entirely separate pipe lines should be provided for raw, boiled, and refined oil, from their respective storage tanks to the bunghole. In no other way can the purity and color of the refined oil be maintained, unless by the wasteful process of washing out the pipe lines with refined oil before drawing therefrom any quantity of such oil for shipment. When various grades of oil come through a single pipe line, a gauge-glass is sometimes provided on a standpipe immediately in front of the filler, who thus has presented to him at all times a sample of the oil which he is drawing.

As the oil is run into the barrel, the filler, standing by, taps the sides of the barrel with a wooden bung mall, judging by the sound how far up the oil has ascended. When the level of the oil approaches the top of the barrel, the outlet valve from the pipe line is partly closed. The filler then watches carefully until the oil level can just be seen through the bunghole. The swinging pipe is sprung up and swung away, the bung applied, and the barrel rolled to the shipping scales. This operation of filling involves much care, and is expensive in labor. Automatic barrel fillers have been successfully introduced. These are attached to the end of the swinging arm, and descend through the bunghole into the barrel. When the oil level reaches a point within about two inches of the top, it trips a delicately balanced rod which shuts off the supply of oil, indicating to the attendant that the flow has been stopped. With these devices one man can attend to the filling of several barrels at once.

The barrels should lie on their sides on a special floor depressed below the walk-ways of the room, and oil tight. This floor should drain through gratings to tanks below. The tanks will then catch any oil that may occasionally slop over. A dumping tank should be provided for receiving oil improperly packed or returned from customers. A pipe line, terminating in a hose, should be run out to the dock or track for filling tank cars. A similar pipe line should be provided for emptying tank cars shipped in to the mill.

The scales in the filling room should be located between the fillers

The crusher consequently loses 1 cent per gallon on his barrel shipments. In reality he avoids this loss by adjusting his quotations to suit the cost of barreling and by making a special reduction beyond the 2-cent differential in the price of bulk oil. The matter of barrel cost is one that must always be carefully considered in making quotations. The cost of 3 cents per gallon is equivalent to $7\frac{1}{2}$ cents per bushel of seed crushed to make the barreled oil, or more than twice the cost of power and labor for producing this oil. The second-hand barrel market is always the scene of severe competition in buying. Every crusher aims, as far as possible, to secure the return of empty barrels from his own shipments; but when shipment is made to far distant points this may be impracticable. Large consuming centers which are not crushing points are usually the best markets for the purchase of second-hand barrels. Such cities are Boston, Baltimore, and Richmond, for instance. At these cities the price of barrels is apt to be low; while at a city like Buffalo, which crushes much oil but uses little, the buying of barrels is greatly in excess of the selling, and the price is high.

Barrels are bulky in proportion to their weight, and some crushers consequently operate special barrel cars in order to save freight expense. One of these cars appears, incidentally, in Fig. 3, page 12.

Crushers frequently reduce their cost of marketing oil by maintaining tank stations at various large consuming cities. To these stations oil is shipped in tank cars, stored in tanks, and packed into locally secured barrels as required for delivery to the consumer. With the differences in prices of barrels at various points, and the dead loss by paying freight on the barrels, the expense of maintenance of a tank station is often readily assumed. The reduced cost of the empty barrels is also an argument for the establishment of tank stations. One company, for example, from five crushing points shipped oil, which ultimately reached the consumer in barrels, at the rate of 15,670 barrels per month. By building tank stations at six points the demand for barrels at the crushing mills was reduced to 8000 per month, nearly half the entire consumption of barrels being provided for, at a greatly reduced price, at the tank stations.

The capacity of the barrel secured for a stated price is important. Thus a 51-gallon barrel, costing \$1.25, which it costs 25 cents additional to deliver, cooper, and fill, stands the crusher $\$1.50 \div 51 =$

\$.0294 per gallon. A 47-gallon barrel at the same price would cost him \$.0319 per gallon. He could afford to sell oil in the former barrel at one-quarter cent less per gallon.

The shape of the barrel is also of some importance. While, theoretically, a barrel having a wide bulge, or relatively large difference in the center and end diameters, is stronger on account of the trussing effect of the arched staves, it is found in practice that a difference in diameter of about 3 inches is best. Such a barrel will retain its hoops better and will pack closer in shipment. New barrels for oils are usually built with about this amount of difference, less material being thus used in the staves than when the bulge is greater.

The market price for empties fluctuates so rapidly, and the day-by-day consumption of barrels for shipment is so irregular, that it is essential for the crusher to keep a large stock always on hand. Piles of ten thousand empty barrels adjacent to the cooperage department are sometimes seen. The barrels are given a rough inspection as received, to check the grade and percentage of breakage, and then stored on their sides in the open. Assuming them to be laid on 30-inch centers, and to occupy a space lengthwise of $3\frac{1}{2}$ feet, each barrel requires a ground area, for the first tier, of $2\frac{1}{2} \times 3\frac{1}{2} = 8\frac{3}{4}$ square feet. One hundred barrels would require 875 square feet. A second tier of ninety-nine barrels, a third of ninety-eight, and so on, could be piled on top of this. Theoretically, therefore, a tremendous number of barrels could be piled on a comparatively small ground area; but in practice the pile is seldom over 12 to 15 tiers high. At 12 tiers, 875 square feet of ground would accommodate over 1000 barrels; say, roughly, one square foot of space per barrel, which represents usual practice.

From the pile the barrels are taken as required and stood over the steaming-trough. This is a wooden box, open at the top, over which the barrels are laid with the bungholes downward. A steam pipe runs lengthwise of the box, having a number of vertical outlets which terminate in nipples entering the bungholes of the barrels. Exhaust steam may be, and should be, used, and a cheap valve should be located on each discharge nipple. The steam cleans out the barrel, the drainage flowing out through the bunghole, around the steam-pipe nipple, and into the trough, which conducts it to the sewer. After steaming, the barrels are passed to the cooper, who gives them a

thorough inspection and replaces any broken staves and broken or missing heads. New staves are provided from broken barrels, trimmed to proper width, and inserted more readily in place by slightly loosening the hoops. Second-hand heads may be used, or new turned heads. If there are evidences of leakage between staves, or at the ends of the staves where the joint is made with the head, strips of flagging (preferably fresh-water flagging) are inserted. The barrels are washed with glue or size to make them more impervious, if they have not been previously used for linseed oil. The foreman gives them a final inspection, especially for cleanliness, by inserting an electric lamp through the bunghole, and passes them to the hoop driver. The hoops may be driven up either by hand or by an automatic driver. The hoops draw the staves tightly together and are clinched in position by hoop fasteners. Defective or missing hoops are replaced by new ones, these being riveted up to proper size from strips of hoop iron of suitable width and thickness. The barrels are then painted, one color on the body, another on the heads. The colors vary somewhat with the different crushers, blue and red for the bodies and white for the heads being most common. Red is the cheapest color, green the most expensive, of those commonly used. The painting is very quickly done, the operator holding a very wide brush against the side of the barrel while he spins it around on the chine with one hand. Automatic painting machines are not employed. A new bung is provided for each barrel in the filling room, but the coopers are required to ream out the bungholes to one of three standard sizes.

Barrel paints are obtainable in the forms of dry powder or of paste. The dry paint is dissolved in rosin oil, in the proportion, 18 pounds paint, 5 gallons benzine, 20 pounds rosin. Another formula is, 10 pounds paint, 2 gallons rosin oil, the latter consisting of 8 gallons of benzine to 40 pounds of rosin. This two-gallon solution sufficed to cover 26 barrels. Using paste paint, 33 barrels were covered with 10 pounds of paste dissolved in $1\frac{1}{4}$ gallons of rosin oil of the 8 : 40 strength. The rosin gives luster to the painted surface, but the paint does not dry well. A drying oil, like linseed, would, however, be too expensive for use in painting linseed-oil barrels.

The barrels are rolled to the filling room and weighed, empty, the tare weight being stenciled on the head. After filling, the gross weight is also stenciled, as well as necessary brand and shipping marks.

Usually one head is reserved for the name of the crusher and the brand, the other for the gross and tare weights and shipping mark. It is desirable to have separate scales for weighing the empty barrels.

The best barrel that can be prepared will absorb more or less oil. Whether this loss should be borne by crusher or consumer is a mooted question. Since it amounts to only 1½ to 2½ pounds per barrel, usually, while the difference in scales is seldom less than this, differences in weight of less than one-half gallon scarcely give ground for complaint on the part of the consumer. That the differences, if any exist, should be rather in favor of the crusher on both gross and tare weights, is but natural. Many consumers overlook the fact that by improper drainage of barrels they may easily lose from one-fourth to one-half gallon of oil without any fault on the part of the crusher. Automatic registering certified scales for shipment would remove much of the cause for complaint now found in the case of barrel shipments.

High temperatures warp the barrels and cause leakage. Cooperage for shipments to southern points should be unusually sound. A shipment of oil should never be left uncovered in the sun on a dock or vessel deck. Care in handling is also necessary if barrels are to be delivered to the consumer in tight condition.

A cost statement covering the operation of one leading crushing mill for eight years prior to 1900 showed an average cost of cooperage, including every item of labor and materials from the receipt of the empty barrel to its delivery, painted, in the filling room, of 8 cents per barrel. The cost is at least double this at the present day, even under good conditions. Moreover, the labor of filling, a considerable expense, should also be charged against cooperage. The cost of painting barrels alone is now from 3 to 5 cents each, or say half the cost of press cloth per bushel of seed. The following table illustrates the labor elements entering into the cost of cooperage.

1902–03: Mill Number.	1	2	3	4
Barrels shipped per month	5600	2400	1100	1400
Number of coopers employed	9	2	3	2
Number of fillers employed	5	2	1	1
Barrels per cooper per month	622	1200	367	700
Barrels per filler per month	1120	1200	1100	1400

The wide differences in cooperage labor are due to the differences in the grades of barrels purchased. During the first four months of 1903 the average cost of barreling oil in one mill, not including the labor of fillers, ranged from $.0210 to $.0288 per gallon. By the end of the year the cost in this particular establishment had reached an average of $.0279 per gallon. An effort was then made to keep a more accurate record than had heretofore been obtained of the total excess cost of shipping oil in barrels, in order that the general business of crushing seed should not have to bear an expense for which increased revenue was obtained. This involved accurately balancing the stock of empty barrels each month, totaling the shipments in barrels, and charging to the barrel expense most of the filling-room labor. The result, as stated, was to show that the established 2-cent differential was entirely too low, and to justify lower prices for bulk oil.

The increasing cost of barrels has led to some use of iron drums. These are high in first cost, but durable and tight, and may be more widely introduced. Second-hand fish-oil casks, ranging in capacity from 150 to 350 gallons, are sometimes used for short shipments to customers who are equipped to handle them. These casks cost less and can be coopered for less per gallon than barrels, but on account of their great weight must be carefully handled. Half-barrels, always a nuisance, must occasionally be provided for.

The oil-tank car, originally introduced for transporting petroleum products, is a great economizer. There is no loss by soakage, and only one weighing to be made instead of one hundred or more, with reduced chance for error and controversy. Capacities range up to 8400 gallons. The freight rates on bulk oil are the same as those on oil in barrels, in car lots of 60 barrels; but the tank car itself is transported free of cost. As the average oil barrel weighs 80 pounds, or 21 per cent of the net weight of its contents of 50 gallons = 375 pounds, the tank car effects a direct saving in freight of 21 per cent. As the freight on oil frequently amounts to more than the entire cost for crushing the seed, the importance of this saving is evident. Moreover, the tank car can be kept absolutely clean; there is practically no possibility of leakage; and while the crusher knows pretty closely what freight rates will be, he can scarcely know for a week ahead what the price of barrels will be. Probably the only argument possible against the use of oil-tank cars for shipment is that they constitute a

convenient form of storage for customers and tank stations, and are hence apt to be frequently out of commission as a means of transportation.

Before loading, the car should be closely inspected. The dome cap and valve cap should be taken off, the interior cleaned by steam or hot water, supplied through a steam hose, the tank drained thoroughly dry, and the valve cap screwed up absolutely tight.

Scales and scale tanks must be provided for weighing oil pumped to tank cars. A rough check on the contents of the car may be obtained by measuring it. Extraordinarily careful weighing is profitable and justifiable in the case of tank-car shipments.

The oil reaching the consumer by some one of these various methods constitutes the larger part of the crusher's output. In one mill raw oil was 65 per cent of the total production, rising the following year to 69 per cent. At another point raw oil was 82 per cent of the entire output, the other 18 per cent being boiled. Some mills produce no refined oils; one or two refine practically their entire output, having thus a market which is more or less independent of trade fluctuations. While the mill producing no refined oils is working against an impartial market at all times, still the production of pure raw oil constitutes at least nine-tenths of the operation of linseed crushing with regard to expense, complication of operation, and revenue.

CHAPTER VIII.

PREPARATION OF THE CAKE FOR THE MARKET.

Description of cakes.—Disadvantages of hand packing.—Automatic packer.—Cost of operation.—Types of packer.—Sewing.—Bags.—Second-hand sugar bags.—Sizes of bags.—General analysis.—Capacity of bags.—Small domestic demand for cake.—Grinding.—Operation of grinders.—Description of machines.—A complete grinding plant.—Cost of grinding.—Other by-products than cake.—Analysis of cake.—Its value as manure.—Comparison with foreign cakes.—Possibilities for vast expansion of the linseed industry.—Market price of cake.—Its effect on the price of oil.—The cake trade through the port of New York.—Cost of freighting cake to Europe.—Cake weight shortages.—Their cause.—Specifications for the class of cake desired by the foreign buyer.

From each bushel of flaxseed there are derived from 36 to 38 pounds of oil cake. It is convenient to remember, therefore, that 56 bushels of seed (weighing 56 pounds each) produce not far from one ton of cake. The cake is delivered from the trimmer in hard warm slabs about one foot wide, three feet long, and five-eighths of an inch thick, weighing from 10 to 15 pounds each. These slabs, of a color varying from reddish brown to gray, are corrugated crosswise, as a result of the texture of the press mats. They are now carried to the packer, unless this machine is mounted directly at the discharge end of the trimmer, by means of trucks or of a link belt conveyor. Fig. 41a represents a convenient cake truck.

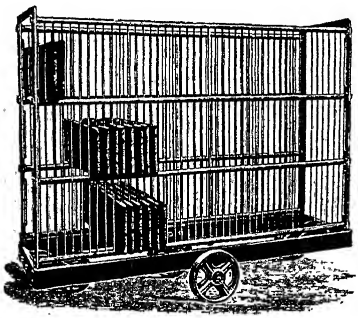


Fig. 41a. — Cake Truck.

Cake was formerly packed by hand, the bags being held up by one man while another placed the cakes in them, the last two or three cakes being driven in tightly by means of a wooden mallet. This operation was wasteful of labor, broke the cakes, reduced the quantity that was contained in a bag, and resulted in loose packages, frequently

badly damaged during ocean transit. The automatic cake packer is now generally employed in all excepting the smallest mills.

One type of automatic packer, as built by the French Oil Mill Machinery Company, is shown in Fig. 42. This machine, which is stated to have a capacity of 9 tons per hour, occupies a floor space of 16 feet 6 inches by 2 feet 6 inches, and weighs 1300 pounds. It is operated from the low-pressure hydraulic system of the mill, and consists of four parts — a horizontal cylinder with plunger, a table to receive the cake, an expanding bag holder composed of steel sheets, and a vertical hydraulic press for forcing the last cakes into the bag.

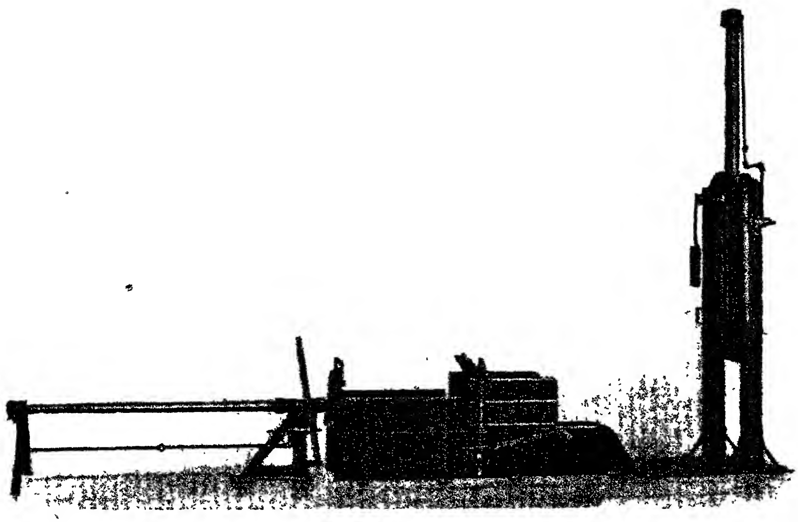


Fig. 42. — French Automatic Cake Packer.

It is operated by drawing a bag over the bag holder, after first placing one foot on the lever which raises the bottom plate and brings the sides together. Sufficient cake is piled on the receiving table to fill one bag, and a valve is opened, admitting the hydraulic fluid to the horizontal cylinder. The piston forces the cake into the bag holder and pushes the bag, with its cake, forward from the steel plates. The piston then returns to its original position and the operator up-ends the bag, driving two or three wedging cakes with the vertical press. With these machines from 8 to 14 per cent more cake is packed in each bag than is possible by hand packing, and about one-half the

labor cost for packing is saved. Unskilled labor may be used for their operation. Broken pieces of cake can be packed. Fig. 43 shows the direct-connected packer and trimmer as built by the French Company. This is a very compact and convenient arrangement, eliminating all handling of the unpacked cake after it reaches the trimmer. Unless the cake is to be packed hot, it involves rehandling the cakes between the press and the trimmer, which is a disadvantage. A far more serious disadvantage arises from the absorption of oil from the soft edges by the whole body of the cake, which always occurs when cakes are left to cool before trimming. Certain complications involved in

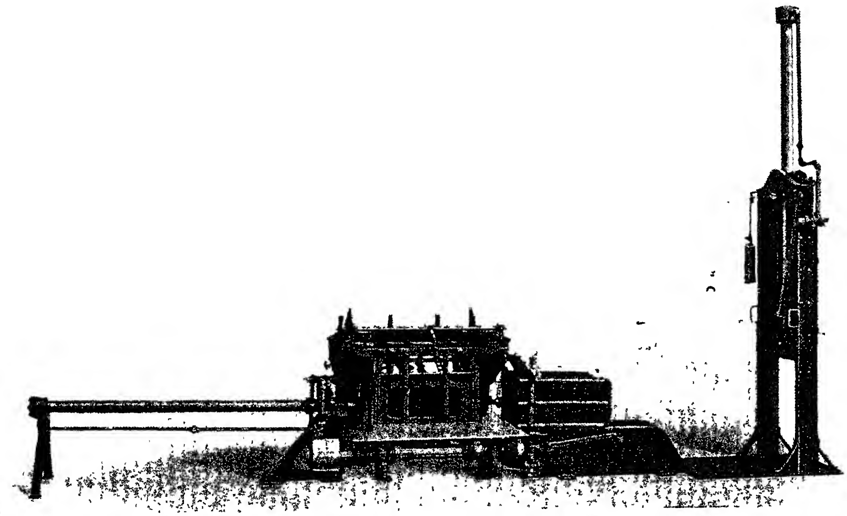


Fig. 43. — French Combined Trimmer and Packer.

packing hot cake will be discussed later. The writer has found it easy to pack, with two French packers, three hundred 350-pound bags in 10 hours, regularly, day in and day out, using the labor of one man and two boys for each machine. This gave a capacity, per machine, of 2.35 long tons per hour, and a labor cost, for packing, of $.0854 per ton.

The Buckeye hydraulic cake packer is a simple vertical hydraulic press, set on a low foundation so as to bring the top of the ram platen flush with the floor when in its lowest position. Each sack, with as many cakes as can be conveniently inserted without difficulty,

is placed upon the platen, and the final wedging cakes are added one or two at a time and forced into place by separate strokes of the press until the desired tightness is secured. Power is derived from the low-pressure hydraulic system. The control is from a vertical hand lever placed at one of the posts, with the handle at a convenient height. Forward movement of the lever closes the outlet and admits the pressure for an upward stroke. Return of the lever to vertical position reverses the valve, cutting off the inlet and releasing the working fluid for return to the hydraulic supply tank. The packer occupies a floor space of 14 by 34 inches, the height above the floor line being 6 feet 4 inches, and above the foundation 10 feet 4 inches. The weight is 1600 pounds.

When discharged from the packer, the bags of cake are sewed at the open end, common white bag twine being used, with burlap needles. Careful sewing is advisable, as the foreign buyer prefers a stout and good-looking package. The bags themselves are of burlap, either new or second-hand sugar bags. New bags are imported from India, the material coming in rolls, usually to New Orleans, where it is cut and hemmed to size. The import duty is subject to drawback when the oil cake is exported, and each lot of about 50 tons of cake has a suitable entry for drawback on the bags attested and submitted to the local custom house. The second-hand bags command no drawback. They cost about 2½ cents, each, less than the new bags at the gross price, less drawback, of the latter, and contain from 10 to 20 per cent less cake. They are the cheaper bag wherever locally obtainable and where adaptable to the size of cake made. They are technically described as "second-hand blue-stripe bags," and when used for linseed cake must be selected from the general run of bags, as mended bags are not suitable for cake. Small try-holes in the fabric, caused by the insertion of the inspector's sampler, are not detrimental. These bags come into the country filled with raw sugar, and after being emptied, are cleaned, dried, and marketed by the bag companies. They may be known by a blue stripe, about 3 inches in width, which runs lengthwise of the fabric in the middle, and consequently appears running vertically on two sides of the made-up bag.

The size of the bag must be accurately determined from the average size of cake made, if economy of material is to be obtained. The width of the bag fabric being fixed, it must be cut in lengths equal to

the length of the cake plus its width plus an allowance for sewing. If this allowance be 2 inches, then for a cake L inches long and W inches wide the length of the bag $= L + W + 2$ inches. The fabric is accordingly cut to this length, and folded over in the direction of its width, i.e., a 60-inch width of fabric makes a bag 30 inches wide. The bottom and open side are machine-sewed before the crusher receives the bags. The width of the bag of course determines the number of cakes it will contain. Thus, if t is the average thickness of the cake, n the number of cakes, the thickness of the bag, when packed, across the cakes, is nt. The width of the cake being W, the distance around the bag, or twice the width plus twice the thickness, is $2(W + nt)$. This is equal to the width of the bag cloth, or twice the width of the made-up bag. If this last width be 30 inches, then for a cake thickness of five-eighths inch, $30 = W + \frac{5}{8}n$. If $W = 12\frac{1}{2}$ inches, $n = 28$; and if the cakes weigh 13 pounds each, the bag should contain $28 \times 13 = 364$ pounds of cake. Variation in the width of the bag varies the quantity of cake contained in like proportion. Thus, at one mill, 2398 bags of proper width held 891,204 pounds of cake, while 5087 bags of scant width (28 to 30 inches) held 1,781,926 pounds, the amount of cake packed in each bag being 370 pounds in the first case against 350 pounds in the second. The difference of 20 pounds, or 5.4 per cent, represented an absolute loss, as the two sizes of bags cost exactly the same. If the bags cost 10 cents each, net, this loss is \$.0054 per bag, or approximately \$.0005 per bushel of seed crushed. Variations in length of bag are still more disadvantageous. If bags are too short, the upper end will show a gap, crossed by stitches, where the bag sewer has made an attempt to cover it. If too long, material will be wasted. The foreign buyer prefers a comparatively light bag, — say 300 to 320 pounds, — and such bags stand transportation better than heavier ones, and many crushers use the smaller bags in preference to the more economical large bags. Many mills, however, show a decided lack of intelligent policy on the bag question. Thus, three large crushers worked as follows:

	Size of Bag.	Size of Cake.
1.	31×51 in.	$12\frac{1}{2} \times 33\frac{1}{2}$ in.
2.	31×50 in.	13 ×34 in.
3.	29×48 in.	12 ×32 in.

In the first instance, the bags gave a 5-inch overlap for sewing, which was more than necessary. The overlap in the second case was 3 inches, about correct. In the third case, where "blue-stripe" bags were used, the overlap was 4 inches. A few short bags, about 48 inches long, were purchased for mill 2. These failed to give sufficient lap at the end for proper sewing.

The second-hand sugar bags run from 28 to 29 inches wide, and are usually not over 48 inches long. They can be used, therefore, only by mills making a short or narrow cake. As large cakes are necessary for large output, it is not policy to figure on the use of sugar bags in any new plant. If the crusher wishes to pack in light bags, it is more profitable for him to make a full-sized cake, packed fewer in number in a comparatively narrow new bag. In discussing bag widths, nothing has been said regarding the loss by side-stitching. This is offset by the stretching of the material, when the bag is packed by an hydraulic cake packer.

It is stated that only 20 per cent of the linseed cake produced in the United States is retained for home consumption, the balance being exported, principally to Europe and the West Indies. Practically the entire domestic demand is for ground cake, or oil meal, and the production of meal is not general among crushers. Most of the western mills do more or less grinding; several eastern mills do practically none. Grinding is expensive, and usually costs more than the premium secured for the meal over cake prices. This has led to a considerable amount of adulteration, principally, however, with flaxseed screenings, which are comparatively harmless and often not detected by analysis, while they increase the percentage of oil in the meal, a desirable point from the standpoint of most stock feeders. In spite of its expense, many crushers equip their works for grinding, in order to be partially independent of the export cake market. Where a high cake freight must be paid, as is the case with all mills not on the Atlantic seaboard, the production of meal is relatively more profitable.

Grinding is frequently performed in two operations, one consisting in breaking the cake, by impact, into small lumps, and the second involving the pulverizing of these lumps. A partial pulverizing of course takes place in the impact mill, and its product is usually screened before feeding to the pulverizer. The Buckeye cake breaker is composed of four knobbed rolls, which reduce the cake quite uni-

formly to about pea size. The four rolls are staggered from the vertical to assist in feeding. Both rolls of the upper pair are alike in size, speed, and surface; of the lower or finer pair the surfaces only are similar, the diameters and speeds varying from each other, and the speeds of both differing from that of the upper pair. The working faces of both pairs are formed, coarse and fine respectively, by longitudinal and circumferential channeling, so as to produce low rectangular teeth. The coarser or breaking rolls are so mated that each tooth on each roll comes fairly opposite a channel intersection as the rolls turn together; the spacing also is such that the cake is broken, not crushed and rolled through. The whole work of cake breaking, properly speaking, is done in the first passage between the coarse rolls. The remaining two passes effect a fine granulating. The second pass carries the broken cake between the lower coarse roll and the upper fine one. To the natural effect of this difference in roll-surface fineness there is added the grating action of a surface speed differential. The result is an action suited to the requirements of a step intermediate between initial breaking and final granulating.

In the third pass there is similarity of surfaces, but pronounced difference of speeds, due to the greater diameter of the bottom roll. The grating action here is very effective in fine granulation of the cake.

Lately there has sprung up in the oil-cake market a demand for "cracked cake," that is, cake simply broken, clean and coarse.[1] Such cracked cake is produced in a most satisfactory manner by this breaker, by allowing the cake to make only the first passage between the coarse rolls, and diverting the broken cake thence to a conveyor for delivery to the sackers. By suitable adjustment of the machine any desired grade or coarseness of cracked cake is readily produced. All four rolls are geared together, and the whole train is driven by twin belts on large pulleys, keyed to the extended ends of the lower coarse roll shaft. Check boards are of iron, fitted and machine bolted into place. Adjustment for cake thickness and for fineness of final pass is provided for by simple and permanent wedge devices. Roll shafts are of one piece each, continuous through the rolls. The speed is from 80 to 120 revolutions per minute. The floor space

[1] Many purchasers prefer this, on the ground that such meal is less liable to adulteration; but as adulteration may be effected at the crushing rolls, the use of "pea meal" is not a certain safeguard.

occupied is 48 by 40 inches, the height 45 inches, and the weight 3225 pounds.

For grinding the granulated cake thus produced the attrition mill is usually employed. This can be set for any desired degree of fineness. Its power consumption is high.

A largely used type of grinder consists of several series of hinged wrought-iron bars, revolving about a shaft which turns at 1200 to 1400 r.p.m. These bars are spaced about three-fourths inch apart in the clear and swing through openings in a cage. Fig. 61 represents a machine of this type. The cakes fed into the machine are struck by the bars with tremendous force, and the fine particles pass through the bars of the cage. From under the cage the meal is taken by means of a belt and bucket elevator to an overhead rotary screen, which discharges the fine meal to bins and returns any coarse particles to the grinder. The power consumption of one machine of this kind, including screen and conveyors, etc., was 100 horsepower for a meal production of 50 tons daily. The crusher only was operated by a 10½ by 17 inch steam engine at 220 r.p.m., the initial steam pressure being 90 pounds, and the engine cutting off at seven-eighths stroke. This high power consumption was partly due to a poor driving arrangement, and was subsequently reduced. Under good conditions an output of 10 tons of meal per hour was secured from a similar machine, for which 60 horsepower was required. This provided power for the crusher only. The total cost of making one ton of meal from cake was from 90 cents to $1.00, including power, labor, bags, repairs, and interest, but not shrinkage. The shrinkage in grinding meal is quite heavy, being due to a slight extent to the actual loss in dust, and to a greater extent to the drying of the meal. Meal bags cost slightly more than cake bags, in proportion to their contents. Compressing the meal to reduce its bulk has been tried, but without commercial success. From the storage bins the meal is spouted down into bags. It can be packed at less expense for labor than cake. Stands for the bags, and in some cases automatic baggers, cheapen the operation of packing. The latter machines are of the same type as those used in flour mills.

Practically the only by-products of linseed oil are cake and meal. The ground seed has a place in the United States Pharmacopœia, and is used for poultices, for making a tea, and occasionally as a constituent

in concentrated feeding stuffs, but the market thus afforded is from the crusher's standpoint infinitesimal. A lawn dressing was at one time prepared from "new-process" meal, which is always difficult to sell. This was advertised to contain from 3.4 to 4.4 per cent of nitrogen, from 1.0 to 1.2 per cent of phosphoric acid, and from 1.0 to 1.1 per cent of potash. It was to be applied in moist cloudy weather in the proportion of 50 pounds of meal to 2500 square feet of ground. The comparatively coarse meal resulting from the "new process" (of percolation, discussed elsewhere) was ground in two 24-inch Cogswell attrition mills.

The reasons for the limited domestic demand for oil cake will be discussed in a later chapter. It should be noted that the average oil cake or pure meal contains from 4 to 7 per cent of oil, and up to 36 per cent of protein, of which 85 per cent is digestible. The value of the manure voided from the feeding of linseed cake is estimated to amount to not less than $16.00 per ton of cake. In the export market, especially in England, American linseed cake is often received at a discount only, on account of the low percentage of oil which it contains. Scientific feeders assert that oil in percentages above 6 is not desirable; but the foreign farmer has not yet accepted this dictum. Cakes produced abroad contain much more oil, sometimes as much as 20 per cent. With cheaper seed, a lower cost for working, and an immediate cake market at high prices, the foreign crusher is primarily a cake producer, the oil being his by-product, sold at such low prices that it finds applications almost unknown in this country. Education of the American farmer to a realization of the value of oil cake, with inevitably changed agricultural conditions, may eventually result in the domestic marketing of our annual output of 350,000 tons of cake, valued at say $7,000,000, with a consequent decrease in the cost of oil, its extended application, and the enormous growth of the linseed industry with resulting benefits to agriculture and commerce. Few features of the business present such possibilities for its expansion as the domestic marketing of the cake at good prices.

Cake has been sold for as much as $85 per ton, its present price ranging from $18 to $25, with meal from 50 cents to $1.00 per ton higher. No quotation of price on linseed oil is ever made without reference to the value of cake, a difference of 1 cent per gallon in the cost of oil, corresponding to 2½ cents per bushel in the worked

cost of the seed, being effected by a difference of about $1.40 per ton in the price of cake. The differential against meal is less than the cost of grinding, but is offset, at western points, by the saving in freight. Meal is sold in carloads, cake usually in lots of 50 tons. As packed, the bags are trucked to the scales, each bag being stenciled with the lot number only, as a general rule. Brands are seldom used on the bags, and it is not common in this country to brand the cakes themselves, a practice almost universal abroad. The price of cake has a considerable effect upon the most economical method of operating a mill. When cake prices are high, oil prices are low, and *vice versa*. The former condition justifies increased output at a small sacrifice in yield of oil. It sometimes leads, also, to the neglect of screening the seed, or to the intentional mixture of impurities with the seed. When meal is sold, high prices are a temptation to adulteration, too readily practicable without detection; but it is to the credit of the crushing interests generally that meal adulteration is rare, and indeed probably never practiced among the better known interests, while the comparatively slight amount of sophistication which is practiced is steadily decreasing.

Most of the oil cake exported from this country passes through the port of New York. The ocean freight rates to the ports of Liverpool, London, Glasgow, Bristol, Antwerp, and Hamburg range usually from 5*s*. to 13*s*. per ton. From 1898 to 1906 the annual receipts of oil cake at the port of New York increased from 302,483 bags to 624,963 bags, the exports from 172,714,200 pounds to 299,913,175 pounds, while the exports of oil meal, which increased from 1898 to 1904, have since decreased to about the old figure of 14,000,000 to 15,000,000 pounds, valued, however, at an increased price of $1.513 per 100 pounds.

The shilling rate of 24.2 cents per 2240 pounds represents a cost for freight of $.000108 per pound, or say $.004 per bushel of seed worked. A rough average rate of 10*s*. therefore represents a cost per bushel of $.04, equal say to the costs of labor and power for operating the mill; or equivalent to 1.6 cents per gallon on the price of the oil.

Cake should be allowed to cool before packing. This permits of contraction due to cooling and to the evaporation of moisture, and results in closer packing. Cake thoroughly dried before shipment is less apt to mold or sour during exposure to the atmospheric conditions prevalent during ocean transit. Furthermore, shipment before

the moisture has left the cake results in a loss of weight during transit and serious controversy with the foreign buyer. Returns from shipments from nine mills showed losses in weight ranging from .30 to .89 per cent. At mills where the cake was weighed hot the highest shortages were found. Mills weighing their cake hot in the daytime, packing during the day the cold cake from the night run, experienced shortages somewhat less in amount. Mills weighing all of their cake cold experience very little shrinkage. Losses as high as 3 per cent of the weight have been found in the first 10 hours after pressing, the average temperature of the cakes throughout this period having been 100 degrees. Most of this loss probably occurred during a few moments after removal from the press.

The foreign buyer's preference is for a cake running uniform in per cent of oil, in size, weight, color, and general appearance. He prefers a light cake, of from 10 to 12 pounds weight, a high percentage of oil, a soft texture, a squarely trimmed cake, packed in bags not exceeding 325 pounds' weight, neatly and tightly sewed. He insists upon accurate weights. Some of these requirements are incompatible with economical operation from the standpoint of the American crusher. It is good policy, however, to meet them on all reasonable or non-essential points, thus establishing a reputation for a fairly satisfactory cake which may be more readily disposed of than the average when the cake market is dull.

CHAPTER IX.

OIL YIELD AND OUTPUT.

Daily figures for yield approximate only.—Factors affecting oil yield and output.—Data showing variations in yield with changes in output.—Relation between yield and cake test.—Importance of cake test.—Some specimen tests.—Sampling.—Percolation.—Purification of solvent, method of testing the cake.—An improved method needed.—Daily weight of product.—Inventory while running or while shut down.—Inventory of cake and of oil.—Influence of temperature.—Points to be observed in making stock inventory.—Transportation losses on flaxseed.—Percentage of impurities in relation to yield.—Effect of fineness of grinding.—Tests.—Bad operating conditions.—Weight of cake.—Width of cake.—Relation between the thickness of cake and hydraulic pressure.—Relation between cake and ram diameter.—Actual data.—Methods of increasing thickness of cake.—Relation between yield of oil and output as affected by speed of working.—A specimen case.—Records of experiments.—General analysis.—Conclusions and comparisons.—Increases in output possible without injury to the yield.—Yields from various seeds.—Economy of working Southwestern seed.—General analysis.—Suggested form for daily report.—Necessity for trial or test runs.—Their object.—Subdivision of the mill.—Duration of run.—Equipment.—Method of conducting the test.—Laboratory tests.—Records of data.—Uniform report.

In comparing the production by various mills of oil from flaxseed it must always be borne in mind that what is called the yield is good or bad according to the way it is calculated, and there is no accurate comparison possible excepting that which is based on inventories taken at the close of the run when the mill has no stock of flaxseed on hand. It is desirable, however, to make the figures for yield of oil from time to time, daily, weekly, and monthly, correspond as closely as possible with the facts that are known to exist. It is also desirable to throw approximate information on the oil yield of a mill by resorting to careful and thorough methods of determining the percentage of oil in the cake produced. While such determination gives only approximate indication of operation, these indications are nevertheless the least liable to large error, if properly made, of any that can be obtained, bearing on this subject.

The volume of production per unit of equipment depends mainly upon the weight of cake and the speed of operation, the approximate

general formula for bushels crushed per day being $\frac{5}{8}\,WNH$, in which W = the average weight of cake, N = the total number of plates, and H = the number of changes made, that is, the pressings per hour divided by the number of presses in a set. Two of these factors, cake weight and speed of operation, should, in theory at least, have a positive effect upon oil yield. The following table shows how these and some other factors compared at four typical mills during a series of runs.

GENERAL FACTORS AFFECTING OIL YIELD.

Point Described.	Mills.			
	1	2	3	4
1. Yield of oil, lbs. per bush.	19.43	19.60	19.33	19.50
2. Average cake test, same period, per cent........	5.46	6.01	5.69	5.53
3. Equivalent to oil in seed, per cent..............	38.2	39 0	38.1	38.4
4. Grade of seed worked.....	No. 1 N.W.	No. 1 N.W.	No. 1 N.W.	No. 1 N.W.
5. Average dockage, per cent.	1.62	1.90	1.63	1.58
6. Transportation shortage, per cent..............	.36	....	....	....
7. Bushels ground per stand of rolls per day........	300–450	?	525	550
8. Speed of rolls, r.p.m......	120	170	170	170
9. Bushels per heater per day..	1300	1200	1050	1125
10. Temperature of press room.	cold	warm	cold	warm
11. Weighing of cake........	$\frac{1}{2}$ hot	$\frac{1}{2}$ hot	hot	hot
12. Number of changes per hr...	$\frac{6}{5}$ and $\frac{6}{7}$	$\frac{7}{6}$	$\frac{6}{5}$	$\frac{7}{6}$
13. Weight of cake per sq. in., lbs...................	.0363	.0292	.0376	.0309
14. Pressure per sq. in. = 16 ÷ (18 × 19)..........	7.25	7.62	8.50	8.29
15. Trimming — make of machine..............	Dion	French	French	Rotary
16. Pressure, lbs. per sq. in., on presses............	3300	3600	3500	3750
17. Weight of cake, lbs.......	$15\frac{1}{4}$	$13\frac{1}{2}$	15	14
18. Width of molder frame....	$12\frac{13}{16}$″	$12\frac{3}{4}$″	$12\frac{1}{2}$″	$11\frac{3}{4}$″
19. Length of molder frame...	$34\frac{3}{4}$″	$32\frac{1}{2}$″	33″	$32\frac{1}{4}$″
20. Average ram diameter....	16″	16 to 17″	16″	16″

While conceding that the weight of cake and the speed of working affect the yield, it is not safe to say that any variations in weight of cake or speed of working within the limits of ordinary operation are such as to have injurious effect upon the yield of oil. An increase in the width of cake made at one mill resulted in a sharp decrease in yield, which was found to be due, however, not to the mere fact of the increase in the cake area, but to the fact that the wider cake lapped over the edges formed in the mat by the former narrower cake. This

whole subject will be discussed more at length later. In connection with it, it is interesting to note some comparisons of results obtained at various mills, showing that considerable increases in production per unit may be made without injuriously affecting the yield of oil. In one mill, for example, (A) the daily output was increased from an average of 3836 bushels to 4156 bushels, while the yield figured 19.55 and 19.52 pounds. The change in yield was too small to be considered in comparison with the increase in output. Yet this same mill had run for years at an average output not exceeding 3300 bushels before the two increases referred to were made. In another case (B) the production increased from 178 to 192 bushels per press (average figures), while the yield also increased from 19.52 to 19.58 pounds. In a third mill (C) the bushels crushed increased from 1904 to 2294 daily average, the yield concurrently increasing from 19.44 to 19.51 pounds. These gains in output were made as the result of improvement in details of operation without equipment expenditure. The point to be noted is that they were unaccompanied by loss in yield. The changes made at the three mills were, at A and C, increases in length of cake, and at B and C increases in thickness of cake.

Mention has been made of the importance and advantage of carefully determining the percentage of oil in the cake product of the mill. When the percentage of oil in the seed is known, a determination of the percentage of oil in the cake becomes a simple method of checking the reported yield of oil, since the oil obtained, as oil, plus the oil in the cake must equal the oil in the seed, as shown by the following:

GALLONS OF OIL YIELD PER BUSHEL OF SEED CRUSHED FOR VARIOUS SEED AND CAKE TESTS.

1 bushel seed = 56 pounds. No loss. 1 gallon oil = 7½ pounds.

Percentage of Oil in Seed	34	35	36	37	38	39
Cake Test, per Cent.						
1	2.49	2.56	2.65	2.72	2.80	2.87
1½	2.47	2.54	2.62	2.69	2.77	2.84
2	2.44	2.52	2.59	2.67	2.75	2.83
2½	2.41	2.49	2.56	2.64	2.72	2.80
3	2.39	2.47	2.53	2.61	2.69	2.77
4	2.34	2.43	2.49	2.57	2.64	2.71
5	2.28	2.38	2.44	2.53	2.60	2.68
6	2.23	2.33	2.38	2.47	2.55	2.62
7	2.18	2.28	2.34	2.42	2.50	2.57

Note. — Yield increases .60 pound for each 1 per cent of oil in seed. Yield decreases .30 pound for each 1 per cent of oil in cake.

This check is not absolute because of varying conditions as to moisture in seed and cake, impurities in the seed, etc., which are elsewhere described; but while there are occasional inconsistencies and the actual measured yield may not in all instances compare precisely with the test of the cake, it is nevertheless true that the latter is in the main a very accurate index of whether the mill is operating properly or improperly. One per cent of oil in the cake means one-third pound of oil per bushel, so that for ordinary prices a variation of one per cent in the cake test means an increase or decrease of about two cents per bushel in the cost of operating the mill, an amount which is equal to practically the entire labor cost of mill operation under favorable conditions. It will readily be seen, therefore, that increases in volume of production which involve any increase in cake test, and consequently loss of oil, are apt to increase rather than decrease the expense of operation.

The actual percentage of oil contained in commercial cake varies from 4 to 7 per cent. A fair figure, if continually maintained, when the cake is properly sampled, is 5 per cent. Percolated meal left after the extraction of oil from flaxseed by the naphtha or "new" process contains from 1 to 2 per cent of oil, the average being between 1¼ and 1½. The cake left from cold-pressed oil will seldom run lower than 15 per cent. In Europe, where flaxseed is expressed principally in order to obtain the cake, the tests run very high. The following are some of the percentages of oil obtained from various samples tested from 1898 to 1902:

Dewkins (Russian).....	13.60	Capara (Spanish)........	9.62
Kosan (Russian).......	12.86	J. J. R. (Russian).......	12.26
Bull (Calcutta).........	12.96	Chockloff (Russian).....	9.56
Manoff (Russian)......	10.99	(Russian).......	22.00
		Liutows (Russian).......	10.29

The foundation of a properly representative cake test is in the sampling. Improper sampling is the usual cause of inconsistent tests. The fact that two mills working the same quality of seed may report widely differing yields of oil with practically the same per cent of oil in cake is usually an indication of partiality in sampling. In times past it was the idea to deliberately select good cakes, and in almost every plant a point was made of avoiding any cake that was perceptibly bad and

higher in per cent of oil than the average. This was of course wrong. The selection should be made absolutely at random, and if so made it is natural to expect that occasionally a comparatively high test will be obtained. The infrequency of such a test, however, will prevent it from affecting the general average to an undue extent. No effort should be made to obtain a top cake, a middle cake, or a bottom cake, or a cake that has had the full time, or a cake taken at any certain hour during the day. The best selection possible would be that by some one blindfolded who had never handled a linseed cake before. In default of this, the selection should be made by some one about the mill who is least qualified to judge of the cake, not the press-room foreman, nor the mill manager, but some office employee or some one from another department whose choice will be a random choice, so that the bad will show up with the good and the average for the month will truly represent the average work of the mill. This selection should be made at frequent intervals; at least hourly and preferably half-hourly, during the day and night. A quarter section should then be sawed out of each of the 24 or 48 cakes thus obtained. Instead of testing the sawdust, as is usually done, these quarter cakes should be ground in a cake grinder and the resulting meal thoroughly mixed and sampled in an automatic sampler down to the proper amount for testing.

The proper sample having been obtained, the method of testing consists usually in percolating a sample of meal with a solvent, such as naphtha, ether, or bisulphide of carbon, one of the two last named being commonly employed. Ether is not quite as powerful a solvent as carbon bisulphide, but possesses the advantage of being readily obtained in a condition of purity. The superior solvent power of carbon bisulphide, added to its usual impurities, which consist of a solid residue left upon evaporation, are apt to make tests in which that substance has been used show an unduly high percentage of oil. This solid residue consists of free sulphur. The amount of it in a given lot of solvent appears to vary from time to time, being augmented by exposure to light and air. The solvent should be repeatedly purified by distillation, kept in a dark place in an opaque and tightly corked bottle, and frequently tested to ascertain what percentage, if any, of sulphur is left as a solid residue upon evaporation. This test is made by taking a weighed quantity of bisulphide and allowing it to evaporate in the sunlight, and finally over a water bath, to

constant weight. When using the solvent thereafter in making tests an accurate record should be kept of the quantity of solvent used and a deduction made from the percentage of oil found representing the amount of solid residue contained in the solvent.

The standard method of testing the cake is as follows:

One hundred grains or 10 grams of the ground sample of cake are accurately weighed on a piece of glazed paper. A percolating tube three-fourths inch in diameter and 11½ inches long is plugged with cotton, on top of which the sample of meal is poured, and another plug of cotton placed on top of the meal. The solvent is then poured into the tube until the latter is about full, and is allowed to percolate through the meal and discharge into a three-inch evaporating dish placed underneath the tube. For complete extraction of a 100-grain sample the tube should usually be twice filled with the solvent. The completeness of extraction is determined by observing whether the final trickling from the tube leaves an oil stain on paper and also by making an additional extraction in another evaporating dish and observing whether the fluid which runs through evaporates completely. After making a few tests with one particular solvent it is usually not difficult to judge of the amount of solvent required for a sample containing a normal percentage of oil. After complete extraction, the evaporating dish is placed in a desiccator and set in the sunlight. When the odor of solvent can no longer be detected the dish is kept on the water bath for fifteen minutes, after which it is weighed. The weight of oily residue in grains or decigrams, as the case may be, is the percentage of oil in the sample of meal, providing no correction is necessary for impurities in the solvent. To make these tests of cake truly representative, regard should always be paid to the percentage of moisture in the cake. An increase of moisture with the same percentage of oil means, of course, a higher percentage of oil in the dry cake, and the operation of a mill cannot be judged wholly from its cake tests without bearing in mind also at all times its moisture test.

There is need for a simpler and quicker method of testing cake. By the present method a considerable delay is necessary in order to evaporate the solvent. The testing is rather expensive and there is great room for error. A volumetric method would be desirable; possibly one could be developed from the phenomena of color imparted to solvents by even minute traces of oil in solution. The method of testing given is, of course, that employed by the mills, the tests being often made by comparatively unintelligent men. In laboratory testing, various refinements are introduced, such as the condensing of the evaporated solvent, etc.

Aside from the question of testing the cake, the crusher determines the correctness of his operation by weighing the amount of oil produced, usually every twelve hours. The weight of cake is likewise ascertained, and it would seem reasonable to expect that the sum of the two should be equal to the weight of seed crushed. As will be

shown in a later chapter, there are reasons why this is not the case. The combined weights of oil and cake are always less than the weight of the seed delivered to the mill, the former losing weight, probably in storage and certainly during working. Furthermore, the oil and the cake, particularly the latter, lose weight after their production. The daily yield of oil as usually calculated by dividing the weight of oil produced by the total weight of the oil and cake expressed in bushels of 56 pounds is therefore not correct. If mills were generally equipped with scales for weighing the seed fed to the rolls each day, a more nearly correct, though still approximate, record of yield might be obtained. Even with such facilities, and in the absence of any accurate method for ascertaining the quantity of seed in bulk storage, the crusher never knows what his actual yield is until he exhausts his supply of seed. This is usually done intentionally once or twice a year, and is apt to occur oftener. With a mill empty of seed, an accurate inventory of oil and cake (not an easy inventory to make) shows the actual yield from mill operation, both of oil and of cake, which may be defined as the weight of each actually on hand or credited from shipments as a result of each bushel of flaxseed charged to the mill. At this time the crusher may be so unfortunate as to find himself short 10,000 to 20,000 bushels of seed from the amount charged to him on his books, such a difference often making the difference between a profit and a loss on the season's operation. Against such a calamity various methods of day-by-day hedging have been devised, which will be suggested later. Occasionally a crusher "comes out" ahead on seed, i.e., finds that he has more seed on hand than his books call for. His cake and oil may, upon inventory, prove either over or short of what his books show.

The inventory of cake is usually conducted by counting the bags and single cakes in piles. The average weight per bag and the average weight of each cake must be known. Loose meal is difficult to estimate. The cake can, of course, be all weighed, if desired. The oil is taken by measuring the depth of oil in each tank and computing the number of gallons. The specific gravity of linseed oil being .93, its weight per cubic foot is 59.1 pounds, or the gallon of $7\frac{1}{2}$ pounds contains $7.5 \div 59.1 \times 1728 = 219$ cubic inches. This is correct for a temperature of 60 degrees F., but as linseed oil expands .045 per cent of its volume for each degree F. that the temperature is elevated (.081 per

cent per degree C.), the temperature of each tank must be taken and its contents corrected accordingly; a difference of 22 degrees in the temperature making a difference of about 1 per cent in the contents of a tank. The expansion of linseed oil by heat is nearly twice as great as that of water.

For simultaneously taking the contents and the temperatures of the tanks, a weighted maximum and minimum thermometer should be used, attached to a standard steel tape. This form of thermometer gives the average temperature from top to bottom of the oil, and maintains its indication until readjusted after the readings have been taken. Every crusher keeps a list of his tanks for oil, with a tabulation of the contents in gallons for each. During the gauging of the tanks it is of course important that the outlet valves be all locked and the keys secured. For ease and accuracy of stock inventory, the mill should be reduced as nearly as possible to a quiescent state; the seed tanks and bins having been made absolutely empty, the heaters cleaned out, all cake and meal bagged if practicable, all foots barreled or tanked, the filter presses empty and out of service, pipe lines drained, and all oil in barrels either weighed or dumped. Such an absolute shut-down is expensive, and in some mills never occurs, approximate inventories being taken from time to time when a relatively low stock of seed furnishes a favorable opportunity. With suitable equipment for rehandling and reweighing seed, an accurate inventory might be taken at any time; but few, if any, mills have such equipment. When taking an inventory while the mill is in operation, the seed in process of crushing, i.e., in heaters, presses, conveyors, and troughs, whether in its original condition or partially or wholly as oil or cake, must be carefully taken into account.

The first impairment of yield to which the crusher must submit is that due to transportation losses of seed before it ever reaches him. He buys his flax in primary markets, from which it usually passes, before reaching him, through the hands of common carriers and public elevators. Both lose some of the seed. One of the controlling factors in the strategic location of a mill is therefore its service by these utilities. Water transportation is almost always less severe on the seed quantities than rail transportation; and the latter varies widely in character in different parts of the country. Transportation by rail from Buffalo to New York was for some years accompanied by

notoriously heavy shrinkages of flaxseed, while that from Minneapolis to Chicago resulted in far lighter losses. Proper cars, properly lined, greatly decrease the losses in rail shipments. Elevators differ in reputation for shrinkage as widely as the railroads, and occasionally crushers think that the shrinkage is more than is accidental or inevitable. Transportation on the Erie Canal from Buffalo to New York has the desirable feature that the canal boatmen stand the shrinkage, i.e., the crusher deducts the value of any seed shortage from the freight. The lakes transportation of flaxseed is governed by the rule that the vessel is responsible for shortages in excess of one-half bushel per 1000. Lake shipments show practically no shrinkage if made in steel bottoms. Over a period of several months, the shrinkage in transportation by rail from Buffalo to a seaboard mill was 3.62 bushels per 1000, a large part of which was found to occur in the lighterage between the railroad elevator and the crushing mill. In fact, the shrinkage was greater during the few miles of harbor transportation than the average shrinkage on shipments via canal all the way from Buffalo. A western mill experienced an average shortage of 1.01 bushels per 1000 on a four-mile rail switch.

The amount of impurities in the seed also has a decided bearing on the commercial yield. If the crusher receives a net 56 pounds as a bushel of seed, he may obtain say 19.5 pounds of oil and 35.5 pounds of cake, and lose 1 pound of material by shrinkage. If he is so fortunate as to receive with each bushel of seed 1 pound of accidental impurity gratis, he may still undergo a 1-pound shrinkage, and even if he obtains no oil from the screenings he will produce from each bushel 19.5 pounds of oil and 36.5 pounds of cake. If cake is worth one cent per pound, his increased revenue is therefore one cent per bushel. In fact, however, he obtains some oil from the impurities, when these are contained in small percentages, thus increasing his yield.

Another factor affecting the yield of oil, which does not have such a direct relation to volume of production, is the character of grinding. This has already been discussed in a preliminary way.

For good work, no stand of rolls should be expected to crush much more than 500 or 525 bushels per twenty-four hours. This is assuming that they are in good condition. If the rolls are in bad shape they will not crush anything like this quantity of seed. The average cake test when running three stands of rolls per set of presses was, in one

mill, 4.90, and when running two stands of rolls, 6.10. These rolls were in very bad condition.

The influence of fineness of grinding upon yield is inevitable. The comparatively heavy expense of grinding the rolls is for this reason cheerfully undertaken. Experimental data as to the exact relation between the fineness of the meal and the yield of oil are lacking, and, in fact, determinations of fineness by means of sampling sieves are difficult and inexact, because the operation of sifting makes the meal finer. A series of tests made in order to determine the combined influence of thorough grinding and time of pressing gave, first, with all rolls running and six pressings per hour on seven presses, an average yield of 19.65 pounds, with a cake test of 4.90 per cent; second, with one-third the rolls shut down and six pressings per hour on six presses (faster operation), 19.16 pounds oil yield and 5.67 per cent cake test. The decreased yield of oil in the second tests was deemed to be due to the poorer grinding rather than to the faster operation.

The weather has some effect on the yield of oil, it being easier to keep the meal hot while in the presses during the summer months. The seed would, aside from questions of quality and percentage of oil, affect the yield of oil according as it contained more or less moisture. Theoretically, old and dry seed contains the more oil, but press-room operators know that it is much more difficult to so temper the meal as to get the oil out of old or dried seed.

Bad habits in the press room are frequently accountable for a falling off in the yield. The men will get off the schedule time and try to make up a pressing, so that in some cases the cakes are left under pressure for a very few moments only. Cakes have been left in the presses over Sunday so that the men could get home promptly Sunday morning. In mills not equipped with automatic change valves, the men will not change from low to high pressure at the proper moment. They will sometimes fail to insert the cakes in the press straight. Other matters equally under executive control are to make sure that the change cocks are all seated tight and that the rams are not leaking; that the hydraulic system generally is tight, so that the accumulator never rests on the blocks; that the meal is properly heated and moistened in the heaters; and that the working over of the foots is so arranged that this material is thoroughly distributed and gradually mixed with the meal.

The arguments *pro* and *con* the use of single or double hair mats, or bare plates, are given in Chapter IV. The advantages of the automatic change cock for regulation of pressure, and the influence of steam-jacketed side walls on the presses, are stated in the same chapter. The economical advantages of automatic trimming, and the proper methods for handling foots, with the bearing of these subjects on yield, have also been treated. The number of plates in the press has absolutely no bearing on mechanical factors affecting yield, this number being limited solely by the capacity of a man of fair stature to lift the cakes up to the full height of the press. Pressmen are usually tall, but presses must not be built too high.

The question of weight of cake has a direct bearing on output. If it can be shown that especially long, wide, or thick cakes can be made without decrease in the yield of oil to an injurious extent, an immediate opportunity for improvement would be presented to many crushers.

It would seem natural to assume that with the amount of pressure and the capacity of press cylinder both limited, there is a certain maximum size of cake, beyond which it is not possible to go without diminishing the yield of oil. This is borne out to some extent by the fact that one large crusher, who admittedly gets a high yield of oil, runs with a very light cake, — 10½ pounds, — while another mill, which also makes a very light cake, obtains the best yield of oil that is reported. On the other hand, some crushers, also obtaining good yields, make a fairly thick and large cake.

This matter was investigated by the present writer in 1902, when a considerable increase in thickness of cake was made without any decrease of yield being noted. Later, at another point, the cake was increased in thickness, but as this change was made simultaneously with a change from seven pressings on six presses to six pressings on five, no reliable data exist as to the effect of the change on yield. At another mill the thickness of cake was increased without detrimental effect. At still another, increases were made in thickness and length of cake without detriment. A later increase in *width* of cake resulted in a change for the worse in operation. This, however, was probably due to the fact that the increased width set out the edges over the ridges formed in the old mats, so that the pressure on the center was greatly reduced. With new mats, probably the increased width would not have been a detriment.

In discussing economical weights of cake, reference should always be made, of course, to the hydraulic pressure carried, the diameter of ram, and the maximum distance at the farthest point of the cake from the vertical center line of the ram, in proportion to the stiffness of the platen.

Two main factors should properly be considered: first, the dimensions of the cake as compared with the diameter of ram (the latter being usually 16 inches); second, the thickness of the cake as compared with its surface, which may best be represented by the weight per square inch. This weight per square inch will probably be found to have its economical limitation in the pressure carried, although the limit has apparently not yet been reached.

In four mills the molder frames ranged in inside measurement from $11\frac{3}{4}$ by $32\frac{1}{4}$ inches to $12\frac{13}{16}$ by $34\frac{3}{4}$ inches, the ram diameters from 16 to 17 inches, the high pressure from 3500 to 3800 pounds, the low pressure from 500 to 600 pounds, the weight of cake from 13.8 to 16.0 pounds, and the ratio of former area to ram diameter varied from 1.88 to 2.21, while that of former area to cake weight ranged from 26.6 to 31.0. A temporary change to longer cake at one of these mills was abandoned, not because of any bad effect on yield of oil, but because of the increased consumption of press cloth.

Increase in weight of cake can usually be made by increasing the height of the meal box which supplies the cake former. This enables it to carry more meal, and the absorbing capacity of the former is apparently unlimited. The heaters are elevated to make room for the meal box by placing wood blocks, two or three inches thick, on top of the flanges of the supporting columns. Whenever a mill abandons hair mats either wholly or in part, the increased space for cakes may thus be utilized by making the cake thicker. In many mills there is ample room for cakes 5 to 10 per cent thicker without disturbing the mats. The result is an exactly proportional increase in output without any reduction whatever in the yield.

In considering proposed methods of changing yield or output, where it is expected that both of these factors will be affected, it is necessary to weigh the one against the other. If we assume that seed costs \$1.00 per bushel, in a mill which, making seven changes per hour, crushes 7000 bushels per day, the total production being 57 pounds per bushel of (impure) seed, while cake is worth \$19.00 per ton, net, then if the cost of crushing (press-room cost only) is six cents per bushel,

the cost of oil with a yield of 19.25 pounds is 27.3 cents per gallon. By changing to six pressings per hour, the output would become 6000 bushels, and even if the yield of oil increases to 19.75 pounds, the cost of oil is greater than in the first method of working. For other yields the cost of oil is computed as follows:

Making 7 changes, crushing 7000 bushels, yield 19.25, cost \$.273.
Making 6 changes, crushing 6000 bushels, yield 19.40, cost \$.2757.
Making 6 changes, crushing 6000 bushels, yield 19.50, cost \$.2745.
Making 6 changes, crushing 6000 bushels, yield 19.75, cost \$.272.

This shows that for seed at \$1.00 the yield must be about one-half pound greater to overcome a loss in output equivalent to that due to dropping from seven to six pressings per hour. There is no reason to believe that such an increase in yield can be obtained from such a decrease in the time that the cakes are under pressure. Experiments made at one mill showed for 7 on 7, 6 on 7, and 5 on 7 pressings per hour, respectively, yields of 19.68, 19.73, and 19.72 pounds.

The time of duration of the application of pressure with relation to yield and output permits of some general analysis. We have already given two formulas for daily output, i.e., the approximate formula $\frac{5}{8}WNH$ of the present chapter and the more exact formula of Chapter V, page 53. We now develop a more workable formula than the latter, while a more exact one than the former.

Let W = the average weight of the pressed cake, in pounds,
N = the total number of press plates, or cakes,
H = the relative press speed, equal to the number of changes made per hour divided by the number of presses in a set, and representing the proportion of its capacity which each press produces per hour,
Y = the yield of cake, in pounds, per bushel of seed crushed,
B = the cost of the seed per bushel, in dollars,
C = the net price realized for the cake (less packing, shipping, and freight) per long ton, in dollars,
O = the net price realized for bulk oil, per gallon, in dollars,
P = percentage of oil in the seed,
T = percentage of oil in the cake,
K = cost of producing bulk oil and bulk cake from one bushel of seed, in dollars, less item B,

F = fixed operating costs per hour (administrative, selling, fixed charges, etc., not influenced by the output), in dollars.

The only pure assumption we shall make in this analysis is that the combined production of oil and cake is 56 pounds per bushel. This is about correct for average Northwestern seed containing one-half to three-fourths pound of impurities per bushel, and shrinking in operation to about an equal extent. This being assumed, we have the following relations:

Cake output per hour $= WNH$, pounds,

Bushels crushed per hour $= WNH \div Y$,

Oil produced per hour $= (56 - Y)\left(\frac{WNH}{Y}\right) \div 7.5$, gallons,

$$\text{Cost of operation} = \frac{BWNH}{Y} + \frac{KWNH}{Y} + F, \text{ dollars per hour}$$
$$= (B + K)\left(\frac{WNH}{Y}\right) + F,$$

Revenue from cake $= CWNH \div 2240$, dollars per hour,

Revenue from oil $= (56 - Y)\left(\frac{WNH}{Y}\right)\left(\frac{O}{7.5}\right)$, dollars per hour,

Profit from operation =

$$(1)\quad (CWNH \div 2240) + (56 - Y)\left(\frac{WNH}{Y}\right)\left(\frac{O}{7.5}\right) - (B + K)\left(\frac{WNH}{Y}\right) - F, \text{ dollars per hour,}$$

Oil contained in the seed $= .56\ P$, pounds per bushel,
Oil produced from the seed $= (56 - Y)$, pounds per bushel,
Oil left in the cake $= .56\ P - 56 + Y$, pounds per bushel.

(2) Per cent of oil in cake $= 100\ (.56\ P - 56 + Y) \div Y$.

Formulas (1) and (2) are general formulas for linseed crushing, applicable to any mill crushing commercially pure seed. They would be perfectly general if it were not for the slight modification introduced by small differences in the percentage of impurities and in the shrinkage. Any insertion of values for the constants given leads to results

which are correct for the assumed conditions only. Some useful illustrations may be arrived at by giving reasonable values to some of these constants. Let, for example, $W = 14$; $N = 240$[1]; $B = 1.00$; $C = 22.40$; $O = .40$; $P = 38$; $K = .10$; $F = 4.00$. Then formula (1) becomes

(3) $\frac{6304\,H}{Y} - 145.4\,H - 4$, and formula (2) becomes

(4) $(100\,Y - 3472) \div Y$.

By extending these formulas for various percentages of oil in cake we have the following:

OIL YIELD *VS.* OUTPUT — RELATIVE GAINS.

Cake Test, per Cent.	Cake Produced, Pounds per Bushel.	Oil Produced, Pounds per Bushel.	Profit per Hour, Dollars.	Value of H for Uniform Hourly Profit.
4.00	36.2	19.8	$28.6\,H-4$	1.00
4.50	36.4	19.6	$28.1\,H-4$	1.02
5.00	36.6	19.4	$26.6\,H-4$	1.08
5.25	36.7	19.3	$26.6\,H-4$	1.08
5.50	36.8	19.2	$25.6\,H-4$	1.12
5.75	36.9	19.1	$25.6\,H-4$	1.12

(Computations by 10-inch slide rule.)

For the case assumed, therefore, an increase of 12 per cent in the speed of working counterbalances an increase in cake test from 4.00 per cent to 5.75 per cent. The tendency is to work the mill too slowly, rather than too rapidly, on account of labor conditions. Within reasonable limits, increased speed of working results in greater gains from the increased production than the losses by increased oil percentages in cake amount to. In point of fact, the operating expense does not increase with the output to any such extent as we have assumed. A considerable augmentation of output can always be secured with trifling increases in labor and power costs. Press-cloth consumption does increase with the output, although if increased output is obtained say by increasing the thickness of the cake, it is difficult to see how the consumption of press cloth is increased thereby. Reduced yields of oil accompanying fast operation are not due to the lessened time in the press so much as to the carelessness often resulting

[1] As in a 10-press mill averaging 24 plates to the press.

from the faster operation and the increased rushing of the men. This analysis as applied to almost any mill would justify the rapid operation, with a sufficient increase in press-room force to not overwork the men. Any crusher will admit that the number of his pressings may be increased 12 per cent without increasing the cake test by 1.75 per cent.

It is not always easy to compare the operation of two even similarly equipped mills when the output per press and the yield of oil each differ. A table similar to the above, prepared from formulas (1) and (2) with constants modified to suit the special conditions, permits of immediate comparison. The cake tests and outputs should be compared with those given in the first and last columns of the table.

It is not to be assumed that all increases in volume of production are made at the risk of injury to the yield of oil. Much can be gained in this direction without hurting the yield and sometimes while actually helping the yield, by giving attention to having tempered meal on hand for the men to start pressing promptly at seven o'clock Monday morning; by getting the machinery in such condition that the noon and midnight shut-downs are brief and do not involve a discontinuance of pressure or of pressings; by watching closely the schedule and seeing that all pressings are made on time; and by seeing that whatever weight of cake is fixed upon is regularly made by the men without permitting them to make a hollow or irregular cake by improperly spreading the meal on the molder when rushed.

Crushers guard carefully all information regarding the yield of oil obtained. From 19.50 to 20.00 pounds represents the average of good operation, the latter being an exceptionally fine result when borne out by inventory at the close of the run. This is of course for Northwestern seed, the corresponding cake tests being from 5.00 down to 4.00 per cent. Many crushers think they are doing well when the cake test is held down to 6.00 per cent. Better yields are constantly being secured as a consequence of improved machinery, and even more than this as the result of better operation. The business is becoming less speculative, and crushers now find their profit in the details of press-room operation rather than in jockeying with the seed market. Flaxseed from the Argentine runs about the same as Northwestern domestic in yield of oil, one run giving 19.60 pounds, the seed testing just under 38 per cent of oil. Calcutta seed is very rich in oil, more so than any other flaxseed worked in this country, and one run

gave an average yield of 21.06 pounds per bushel. The domestic Southwestern seed, grown principally in Kansas, is decidedly inferior, containing from 30 to 35 per cent of oil and giving yields of under 18 pounds per bushel, as a general rule. The difference in the cost of the seed and the freight rates make it a desirable material for mills located near the territory in which it is grown. The relatively high percentage of impurity, for which the crusher pays nothing, further adds to the profit in working Southwestern seed. The following calculation will serve to justify the crushing of this grade of seed even without regard to the question of impurities:

ECONOMY OF WORKING SOUTHWESTERN SEED.

Assumed Conditions.

Grade of seed	Number 1 Northwestern.	Number 1 Southwestern.
Cost of seed per bushel, F.O.B. mill	\$ 1.00	\$ .845
Working cost per bushel	.25	.250
Total cost per bushel	\$ 1.25	\$ 1.095
Yield of oil, pounds per bushel	19.50	17.80
Yield of cake, pounds per bushel	36.50	38.20
Value of oil, at 5 cents per pound	\$ .975	\$ .890
Value of cake, at 1 cent per pound	.365	.382
Total value	\$ 1.34	\$ 1.272
Less total cost	1.25	\$ 1.095
Gain	\$ .09	\$ .177

If the difference in yield is more than that assumed, say 2 pounds, at 4 cents difference in price between oil and cake the decrease of revenue by working Southwestern seed is \$.08 per bushel instead of \$.0680.

For seed at \$1.50, oil at \$.07, the difference in price of seed should be \$.10 per bushel; or, to be exact, 1.70 pounds difference in yield at \$.06 (difference in value between oil and cake) justifies a difference in seed price of 10.2 cents.

The general formula is

$$(Y - Y'')(O - C) = D,$$

where Y = yield of oil from Northwestern seed, in pounds per bushel,
Y'' = yield of oil from Southwestern seed, in pounds per bushel,
O = price of oil F.O.B. mill, in cents per pound,
C = price of cake F.O.B. mill, in cents per pound,
D = least difference in price between Northwestern and Southwestern seed (F.O.B. mills) at which it pays to work Southwestern.

The "Oil, Cake, and Seed Report" given below illustrates the method used by one crusher in keeping daily record of yields. Items 8 and 7 give respectively the percentages of clean seed and impurity contained in the material as worked. Items 11 and 12 give the amount of oil actually contained in each, as determined by analysis. Item 13 is the total of items 11 and 12. Item 14 checks the "cake test," by taking the difference between item 13 and the actual yield of oil, item 16, and dividing by the weight of cake. Item 15 is the weight of oil that should be produced to correspond with the cake test, item 5. This is compared with the actual yield, item 16. There are several opportunities afforded for comparing results, in reporting on this basis, and discrepancies should receive immediate investigation. The outline presented does not, however, make any provision for "hedging" against shrinkage, and is in that respect defective.

OIL, CAKE, AND SEED REPORT.

No. .... Period ending ...... 190..

1. Oil made, pounds......................	......
2. Cake made, pounds....................	......
3. Oil in cake (day), per cent..............	......
4. Oil in cake (night), per cent............	......
5. Oil in cake (average), per cent..........	......
6. Water in cake, per cent................	......
7. Impurities, per cent....................	......
8. Clean seed, per cent...................	......
9. Oil in impurities, per cent	......
10. Oil in clean seed, per cent.............	......
11. Impurities, calculated oil, pounds........	......
12. Clean seed, calculated oil, pounds........	......
13. Oil in seed as crushed, pounds...........	......
14. Oil in cake on seed basis, per cent.......	......
15. Theoretical yield, pounds..............	......
16. Actual yield, pounds...................	......
Plus, pounds......................	......
Minus, pounds.....................	......
Length of time under pressure, minutes.......	......
Kind of seed used.........................	......

There are many variable factors entering into the question of yield, and so many of these can only be estimated by actual experiment under actual operative conditions, that it is frequently necessary to run the whole or part of the mill experimentally. Experiments in connection with regular mill operation are annoying, expensive, and often lead to incorrect conclusions. It is better to conduct them by a special force of men, ample in

number. These are trained to operate under fixed conditions and to persist in the securing of accurate data on any point in question. An experiment of this kind constitutes what is known as a "Test Run."

The object of the run is to put the mill under uniform conditions which can be carefully observed and the results analyzed so as to obtain the actual yield of oil and production per bushel, and where these are not what they should be, to ascertain the reasons for their variation from normal.

If the mill is too large for complete observation of all points it can be divided into groups each comprising from two to four sets of presses, and observations made on the successive groups on successive days. In order to derive the best results the mill must be equipped with scales for weighing the seed crushed. If possible the mill should also be equipped with automatic scales, weighing the seed as fed to the rolls, so that this weight can be compared with the weight of product obtained at daily or even half-daily intervals. Where neither automatic nor ordinary scales are available to weigh the seed fed to the rolls, weights between the elevator and the storage bins will answer, providing the bins are very carefully cleaned out at the beginning and end of the test run. In this case, however, calculations of daily results will not be reliable.

The usual duration of the run should be from Tuesday morning to Saturday night. The observer should reach the mill on Friday of the week preceding in order to prepare for the run. A sampling screw conveyor should be attached to the main line of conveyors feeding ground seed to the heaters. This will secure for testing a continuous sample of the meal worked, which can be quartered down by an automatic sampler and tested for oil and moisture. A clean, spare truck should be obtained on which to place odd cakes selected for testing. A clean, light, dry place should be fixed upon, where tests may be made, and the necessary racks, stands, etc., firmly set up, the water bath connected with the steam pipe and a Bunsen burner connected with the gas pipe. A cake counter should be attached to the trimmer and the press gauges all tested and adjusted. The necessary instruments and supplies should be shipped to the mill in advance, these being kept in a special kit, always ready for use.

The bins having been shoveled dry during Monday night (an extra man being on hand to ensure that plenty of seed can be delivered to the rolls while filling, the presses being allowed to run empty), at or about 7 A.M. on Tuesday morning the weight of oil in the weigh tank is taken and this oil is pumped over into storage, while the press troughs are blocked off so as not to deliver any oil to the weigh tank. Immediately upon blocking off the troughs the run begins. After pumping all oil out of the weigh tank into the storage tank the latter is gauged, all pipe connections between it and the rest of the mill system broken or blanked, and the contents of the press troughs again allowed to run into the weigh tank. All oil that reaches the weigh tank and all cake made after the moment of blocking the connection between the press troughs and the tank are included in the test run. At the beginning of the run the amount of meal in the heaters should be carefully measured, the amount of oil and foots in the troughs estimated, and there should be no trimmings on hand. If any trimmings should be found later they should be set aside and not worked up during the test run.

Prior to starting the run the system tank supplying hydraulic fluid to the pumps should be gauged. It is assumed that on the preceding Sunday the weigh tank and press troughs will have been thoroughly cleaned out and the scales adjusted. Throughout the run regular weights must be taken of the seed, oil, and cake, the last named to be weighed cold; oil to be measured, after pumping over to the storage tank, as well as weighed; seed to be weighed between bins and rolls if possible, but at any rate before being put into the bin.

When closing the run on Saturday night the bins are to be allowed to run empty as before, and when the seed has all been run out of the bins and the amount in the heaters is approaching the amount at the beginning of the run, the presses should be gradually discontinued and allowed to drain and finally only one press in each set continued in operation, and this just long enough to work down the meal in the heaters to the original position. After emptying this last press the whole system is allowed to drain for one hour, after which time the troughs are cleaned out, the contents of the weigh tank pumped over and the tank itself cleaned out, and the foots thus obtained all figured as a part of the production, less whatever per cent of foots may be computed to have been produced on the previous Monday before the test began. The system tank and storage tank are both gauged, and the regular mill operation can be immediately resumed. Where this procedure involves too much loss of time, the run may terminate at the usual time of shutting down on Sunday morning.

The cake produced during the test run must be kept separate until cold and then separately weighed. Screenings removed from the seed during the run are to be carefully retained and weighed at the end of the run. The oil product in the weigh tank is to be thoroughly agitated prior to weighing and the percentage of moisture determined. Every hundredth cake as the cakes leave the trimmer is taken aside for testing purposes. These cakes are accumulated for eight hours, all are permitted to cool, and are then ground, and the meal thus obtained sampled down through the automatic sampler until the proper amount is obtained, to be tested for oil and moisture. A careful observation for at least one day, and for a longer period if necessary,[1] is made of the average time each press is under the full pressure, and the results are entered in a book kept for the purpose. Other particulars pertaining to the operation are entered hourly or half-hourly. There should be obtained every twelve hours, samples of the ground seed and oil. These should be tested immediately for moisture. Each sample of ground seed is given two tests for oil, six tests for moisture; the oil sample is given one test for moisture. As a matter of course there will be obtained every twelve hours, as nearly as possible, the weight of seed run, the quantity of cold cake made, and the weight and measurement of oil made. There will be taken throughout the run, every hour, a trimmed cake; while hot, the edges will be broken from this cake and the broken off pieces preserved. When twelve cakes have been thus broken off the broken pieces are thoroughly mixed, pulverized, and tested for percentage of oil. This will show whether the trimming is what it should be. The general results of the run are calculated from the data obtained, and entered on a uniform report.

[1] In some cases this record is accompanied by charts showing ram movements and the behavior of the change cocks, similar to those of Fig. 32, page 83.

CHAPTER X.

SHRINKAGE IN PRODUCTION.

Shrinkage.—Specific examples.—Explanations.—Cause of shrinkage.—Moisture in seed, oil, and cake.—Experimental results.—Relation to yield.—Cake is hygroscopic.—Influence of method of tempering.—Hedging against shrinkage.—"Working net."—Method for more accurately hedging.—Transportation losses.—Usual percentage of dockage.—Example of proposed method of hedging.—General analysis.—Applications to assumed conditions.—General formulas.

ONE of the uncertain things in the linseed business is the shrinkage, that is, the difference between the amount of seed crushed and the amount of oil and cake produced. If, for example, 100,000 pounds of material, including seed and dockage, is pressed, it is found when the run is completed that there have been produced something less than 100,000 pounds of oil and cake; the difference between the two is known as shrinkage. In the past history of the industry there is no evidence that any attempt was made to determine from day to day what this shrinkage was. The mills reported each day the amount of oil and cake produced, which they assumed was equal to the seed crushed. The consequence was that at the end of the year their books would call for a certain amount of seed, which actual inventory would fail to find. On account of the difficulty of inventorying flaxseed in bulk this discrepancy was seldom discovered until the mill ran out of seed. It then became necessary for the manufacturer to charge up a loss which sometimes was sufficient to make the difference between profit and loss on his operation. The accurate inventory of flaxseed in bulk storage is therefore a matter of vital consequence to the producer. Estimates as to what this shrinkage should properly amount to varied from 1 per cent to 4 per cent of the amount of seed crushed.

Cases have been known of shortages exceeding 3 per cent of the total amount of seed charged to the mill. In one case there was experienced a shortage of 16,800 bushels of seed and 7800 gallons of oil, which was applicable to about 1,250,000 bushels of seed crushed. The low yield

of oil in this case was due to a mode of operation now known to have been wasteful. The mill had been audited some time before while a considerable quantity of seed was on hand. Some effort had been made to divide the seed stock exactly among the various tanks employed for storage, and it was assumed that a certain tank contained the amount of seed specified. What was contained in the rest of the plant was so small that an accurate inventory was easily possible, and this showed a seed shortage of 5972 bushels, an oil overage of 7107 gallons, and a cake overage of 106,000 pounds. Such a report could not be considered bad from a standpoint of shrinkage alone, but the yield of oil thereby indicated was decidedly unfavorable. However, the mill crushed the balance of seed in store, amounting to about 200,000 bushels. After this was done and the mill was out of seed, a further inventory was taken, resulting in the seed and cake "coming out" even, but the oil coming out 21,500 gallons short.

The only explanation possible with this condition of things was that when the prior audit was made the large tank full of seed, the contents of which were assumed to be as per record, did not have in it the stated amount of seed. If this tank had 3000 bushels less than the record called for, and the mill had reported daily an amount of oil produced sufficiently greater than the amount which it did produce, it would have been quite possible for it to "come out" even on seed and short of oil, with a yield about one-half pound less than its records indicated, as shown in the following figures:

Stated.	Actual.	
205,534	202,534	bushels seed on hand
7,421,304	7,421,304	pounds cake produced
543,982	522,000	gallons oil made
205,378	202,430	bushels seed worked
19.87	19.35	yield

Thus converting a 3000-bushel seed shortage into a 22,000-gallon oil shortage.

The above instance exemplifies a conspicuous case of shrinkage, made more conspicuous, however, by incorrect reports of oil weight. A normal and reasonable amount of shrinkage would be a much lower per cent. Experience would indicate that 2 per cent, or say

nearly $1\frac{1}{4}$ pounds per bushel, is an ample allowance with Northwestern seed.

The interesting question to the manufacturer is, what is the cause of this loss and how may it be avoided? Some of it is no doubt due to sundry wastes in and about the mill, the slopping over of troughs and tanks, the tracking away of meal by the men, spills of seed, etc. These losses are very small. Shrinkage is due to the fact that seed as received by the mill and as worked contains from 6 to 9 per cent of moisture, an amount which is usually not equaled by the moisture in the oil and cake shipped from the mill. Eliminating the small wastes due to careless handling, the general rule may be expressed thus: that the shrinkage is equal to the difference in weight of the moisture in the seed and the total moisture in the oil and cake. It is pretty well established that merchantable oil contains practically no moisture. The rule may therefore be reduced to the simple form that the moisture in the cake must equal the moisture in the seed; and as the cake constitutes two-thirds of the weight of the seed, it is necessary for the percentage of moisture in cake to be half as much again as the percentage of moisture in the seed — that is, seed containing 8 per cent of moisture must produce a cake containing 12 per cent of moisture if no shrinkage is to ensue.

The writer's tests indicate that cake contains normally from 8 to 9 per cent of moisture. This is very much too low, for an average quality of seed, to "come out even;" however, a report from one mill showed $11\frac{1}{2}$ per cent of moisture in cake; an English manufacturer reports 12 per cent obtainable. We estimate that if average operation results in $8\frac{1}{2}$ per cent of moisture in cake made from $8\frac{1}{2}$ per cent seed, the shrinkage would be between $1\frac{1}{4}$ and $1\frac{1}{2}$ pounds per bushel. Brannt's text-book[1] gives an illustration of determinations of moisture in seed and cake from which we compute a shrinkage of 1.45 pounds per bushel. These figures serve to strengthen the opinion that the shrinkage is simply a question of moisture in seed and cake.[2]

Since a high per cent of moisture in seed makes the possible loss greater, it seems logical to prefer for working that seed which contains

[1] *Animal and Vegetable Fats and Oils.* H. C. Baird & Co.

[2] Peanut oil is found to be usually produced with a shrinkage of about 2 per cent, which figure closely corresponds with that to be anticipated from the relative percentages of moisture in the seed and cake.

the least amount of moisture — that is to say, old seed. There is another advantage in having dry seed, in that the percentage of oil obtained in a commercial bushel is necessarily greater. The great objection to working old seed is the difficulty of tempering it properly. It is not as easy to obtain a satisfactory yield of oil from such seed as from newer seed.

The only direction in which the manufacturer could hope to accomplish anything toward the elimination of shrinkage would be by increasing the per cent of moisture in cake. It has been established beyond any question that cake will absorb and lose moisture in accordance with atmospheric conditions. A change of 1.7 per cent in weight has been observed in the laboratory. Cake in bags has been found to lose 1.25 per cent from its hot weight during the first week, after which the weight remains constant. By providing appropriate conditions a sample of meal has been increased in weight 2½ per cent; another sample, bone dry, increased 6.7 per cent in twenty hours; a sample of cake, also bone dry, increased .8 per cent in forty hours. It is established beyond question that cake fresh from the press room contains superficial moisture which quickly leaves it. This amounts to from one-half to 1½ per cent. Cake which is weighed hot, just as it comes from the press room, gives an outturn on the other side of the Atlantic about .9 per cent less than on this side. Cake which is weighed half hot and half cold gives an outturn .45 per cent less. Cake which is dry-tempered and weighed partly hot gives an outturn .3 per cent less. By comparing these cases it would seem that the cake when it reaches the other side is reduced to practically a uniform per cent of moisture, and the amount of shrinkage therefore depends solely on the amount of moisture when weighed on this side — that is to say, upon whether it is weighed hot or cold.

A problem pressing for immediate solution in this connection is that of the tempering of meal. The advocates of tempering without the use of steam or water have claimed an equal or better yield of oil with less wear on the press cloth and mats and a better quality of oil. Whether these advantages are really gained is a question. We have already seen that a low per cent of moisture in cake means a loss. The cake being drier weighs less, comparatively, than the cake from an equal amount of seed tempered wet. This makes the cake weight less in proportion to that of the oil, increases the apparent yield of oil, and

lays the way to an excessive shrinkage. If the cake contains 1 per cent less of moisture than wet tempered cake, the apparent yield of oil will figure about 14 points (i.e., $\frac{14}{100}$ of a pound) higher than the actual yield; to be reduced when the mill runs out of seed and accurate measurements of stock are taken.

A definite attempt to systematize results and avoid excessive shortages at the end of the run has been successfully worked out by arbitrarily "hedging" each day to an extent that approximately covers the assumed amount of shrinkage. It was found at the time this system was inaugurated that about $1\frac{3}{4}$ to 2 per cent of hedging was sufficient under normal conditions to quite eliminate shrinkage, and as this per cent about equaled the amount of the dockage in the seed, the method adopted was to ignore this dockage, assuming the net bushels of seed to be equal to the gross bushels of material. This is what is known as "working net,"[1] and while not a scientific or exact system, it did, where honestly and intelligently applied, eliminate the greater part of the shrinkage. A better method, and one that will take into account all the varying conditions, must be devised. A daily determination of moisture in cake will be necessary to obtain exact results; a daily weighing of the amount of seed fed to the rolls will then enable us to absorb the shrinkage day by day instead of letting it accumulate at the end of the year.

The facts which must be considered in this connection are the transportation losses, the per cent of moisture in the cake as weighed, the method of tempering, and the percentage of impurity in the seed.

The losses of seed during transportation to Eastern mills via the Great Lakes and rail, from Duluth, will average at least .1 pound per bushel. Their absorption by the mill will considerably increase shrink-

[1] A typical case of correcting production by "working net" is subjoined:

Seed test, $1\frac{1}{2}$ per cent. Each bushel of seed contains, therefore, 56 pounds of flaxseed and .84 pound of impurity. Assume an oil product of 20,000 pounds and cake product of 36,000 pounds. The total product is then 56,000 pounds, equivalent to 1000 bushels of seed crushed. To this, however, we add $1\frac{1}{2}$ per cent, or 15 bushels, equal to the percentage of impurity, to offset anticipated shrinkage in seed. We then report a consumption of 1015 bushels of seed and a production of 20,000 pounds of oil and 36,000 pounds of cake, giving, per bushel, oil, 19.70 pounds, cake, 35.47 pounds, total, 55.17 pounds, shortage, .83 pound, or $1\frac{1}{2}$ per cent. By thus reporting a consumption of more seed than we have apparently crushed, we are offsetting shrinkage, to the extent of $1\frac{1}{2}$ per cent, in advance, showing a reduced yield now rather than at the end of the run.

age and decrease yield. Shortages in cake weight will average about .3 pound per bushel, and they will serve to increase the amount of shrinkage. The test of seed — that is, the percentage of impurities — appears to be decreasing gradually from year to year. During the year 1902 to 1903 the average dockage worked at one mill was 1.99, at another 1.78. During the following year it was at the former point 1.63, at the latter 1.70, and more recent shipments, via lake from Duluth and thence to Atlantic points, show average dockages about as follows:

Mill (1) slightly over $1\frac{1}{2}$ per cent.
Mill (2) less than $1\frac{3}{8}$ per cent.
Mill (3) less than $1\frac{1}{2}$ per cent.
Mill (4) less than $1\frac{1}{3}$ per cent.

If the present method of hedging to the extent of the percentage of dockage now eliminates shrinkage, we are therefore gradually decreasing our "hedge," and the tendency will therefore be to a gradual increase of shrinkage.

The following is a more satisfactory method for the correction of daily reports in preparing monthly statements, to cover probable losses by shrinkage:

1. Consider any known inaccuracies in figuring (e.g., foots).
2. Include transportation losses, if known.
3. Include effect of hedging on tare weights of cake bags. (These are often figured low.)
4. Add for loss of cake moisture if weighing is done hot.
5. Add for loss due to dry tempering, if any.
6. Assume necessary amount of hedge to be $1\frac{3}{4}$ per cent and add to dockage hedge a sufficient amount to cover.

Assumed example:

Reported crushed, 100,000 bushels; made, 260,000 gallons oil, 3,650,000 pounds cake.

1. Refinery foots worked, 3000 gallons, not credited to oil stock.[1]
2. Average seed shortage on shipments, 3.3 bushels per 1000.
3. Average gain of cake per bag on tares, 1 pound. (Bags containing 350 pounds.)
4. Moisture in cake, lost between press room and shipping scales, $\frac{1}{2}$ to 1 per cent.
5. Cake contains 1 per cent less moisture than normal, due to tempering dry.
6. Average test of seed received, 1.41 per cent impurity.

[1] Foots are always carried in stock as oil.

The following are the corrections necessary:

1. Subtract from oil made	3,000 gal.	(foots)
Leaving, net	257,000 gal.	
3. Subtract from cake made	10,429 lbs.	(= $\frac{1}{350}$, bags)
4. Add to cake made	18,250 lbs.	(= $\frac{1}{2}$ of 1 per cent)
5. Add to cake made	36,500 lbs.	(= 1 per cent)
Making net additions to cake	44,292 lbs.	
Making net weight of cake	3,694,292 lbs.	
Oil, 257,000 gallons =	1,927,500 lbs.	
Product	5,621,792 lbs.	
2. Add for transportation loss	18,552 lbs.	(=3.3 bu. per 1000)
6. Deduct amount of mill hedge	79,268 lbs.	(= 1.41 per cent)
Making net deduction	60,716 lbs.	
Leaving consumption of material as calculated from production	5,561,076 lbs.	
6. Add to this assumed necessary hedge	97,319 lbs.	(= $1\frac{3}{4}$ per cent)
Making actual depletion of material	5,658,395 lbs.	
Equivalent to	101,043 bu.	

Stated Results.		*Actual Results.*	
Oil yield per bushel	19.50 lbs.	Oil yield per bushel	19.08
Production per bushel	56.00 lbs.	Production per bushel	55.64

Based on the uncorrected results, inventory would show:

Seed short	1,043 bu.
Oil short	3,000 gal.
Cake over	44,292 lbs.

NOTE. — The above is based on the assumption (verified to some extent by experience) that the amount of shrinkage is $1\frac{3}{4}$ per cent. To reduce the calculation to a truly scientific basis, the per cent should be determined by daily determinations of moisture in seed and cake, it being equal to $\left(.56\,P - \frac{SC}{100}\right) \div .56$, in which

P = per cent of moisture in the seed.
S = per cent of moisture in the cake.
C = pounds of cake produced per bushel.

The subject of shrinkage, while rather complicated, nevertheless permits of general analysis similar to that given the subjects of output and oil yield, page 133. Retaining the nomenclature there adopted, so far as it is applicable to this more exact analysis, we have

W_0 = the average weight of the pressed cake, in pounds,
N = the number of press plates, or cakes,
H = the relative press speed,
Y = the number of pounds of cake produced per hour,

Z = the number of pounds of oil produced per hour,
P = the percentage of oil in the seed (in the gross bushel),
T = the percentage of oil in the cake,
W = the percentage of moisture in the seed,
X = the percentage of moisture in the cake,
V = the percentage of impurities in the seed.

Assume that the oil contains no moisture. The following relations are apparent:

Moisture in the cake produced per hour, pounds, $= XY \div 100$.

Total weight of product, per hour, pounds, $= Z + Y$.

Dry seed crushed per hour $= Z + Y - \frac{XY}{100}$, pounds.

Total seed consumed per hour $= \left(Z + Y - \frac{XY}{100}\right)\left(\frac{100}{100 - W}\right)$, pounds.

Total seed consumed per hour, in bushels,

$$= \left(Z + Y - \frac{XY}{100}\right)\left(\frac{1.79}{100 - W}\right).$$

Yield of oil, pounds per bushel consumed,

$$= Z \div \left\{\left(Z + Y - \frac{XY}{100}\right)\left(\frac{1.79}{100 - W}\right)\right\}.$$

Yield of cake, pounds per bushel consumed,

$$= Y \div \left\{\left(Z + Y - \frac{XY}{100}\right)\left(\frac{1.79}{100 - W}\right)\right\}.$$

Shrinkage, pounds per bushel consumed,

$$= 56 - (Z + Y) \div \left\{\left(Z + Y - \frac{XY}{100}\right)\left(\frac{1.79}{100 - W}\right)\right\}. \quad (1)$$

For $Z = 2000$, $Y = 3600$, $X = 8$, $W = 8$, this becomes 1.9 pounds, or 3.4 per cent. By "working net," as described on page 145, we would have reported results as follows:

Production per hour, pounds, $Z + Y$.

Consumption of seed per hour, pounds, $(Z + Y)\left(\frac{100 + V}{100}\right)$.

Product in pounds per bushel, $(Z + Y) \div \left\{(Z + Y)\left(\frac{100 + V}{5600}\right)\right\}$.

Shrinkage in pounds per bushel

$$= 56 - (Z + Y) \div \left\{(Z + Y)\left(\frac{100 + V}{5600}\right)\right\}. \qquad (2)$$

The unhedged-for shrinkage would then be (1) − (2), or

$$\left[56 - (Z + Y) \div \left\{\left(Z + Y - \frac{XY}{100}\right)\left(\frac{1.79}{100 - W}\right)\right\}\right]$$

$$-\left[56 - (Z + Y) \div \left\{(Z + Y)\left(\frac{100 + V}{5600}\right)\right\}\right]. \qquad (3)$$

For the values of Z, Y, X, and W above given, formula (2) becomes $56 - \frac{5600}{100 + V}$. For $V = 0$, .5, 1., 1.25, 1.50, 1.75, 2., 2.50, 3.00, and 3.4, this expression = 0, .28, .65, .69, .83, .96, 1.1, 1.37, 1.63, and 1.81; these last figures representing the shrinkages, in pounds per bushel, provided against by the form of hedging known as "working net," when the values of V, or the percentages of impurity in the seed, are stated. Any manufacturer who desires to hedge by "working net" may thus, by ascertaining and employing the appropriate values of Z, Y, X, and W, judge to what extent his method will eliminate the possibility of further shrinkage at the end of the run. For the deduced value of formula (1) it would be necessary, in order that "working net" should entirely absorb shrinkage, to have formula (2) become 1.9, or the percentage of impurity in the seed would have to be over 3.4.

The influence of shrinkage modifies the deductions made from formulas 1, 2, and 3, Chapter IX, in which formulas it was assumed that the production was 56 pounds per gross bushel. The more general relations resulting from the present analysis are as follows:

Revenue from cake, dollars per hour, $= YC \div 2240 = CW_0NH \div 2240$.

Revenue from oil, dollars per hour, $= ZO \div 7.5$.

Cost of seed, dollars per hour, $= \left(Z + Y - \frac{XY}{100}\right)\left(\frac{1.79}{100 - W}\right)\left(\frac{100 - V}{100}\right)B$.

Working cost, dollars per hour, $=\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)K.$

(Screenings not removed before crushing.)

Total cost, dollars per hour,

$$=\left\{K+B\,\frac{100-V}{100}\right\}\left\{\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)\right\}+F.$$

Profit per hour $=\frac{CW_0NH}{2240}+\frac{ZO}{7.5}$

$$-\left\{K+B\,\frac{100-V}{100}\right\}\left\{\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)\right\}-F. \qquad (4)$$

The percentage of oil in the cake is derived as follows:

Pounds of oil in one bushel of material $=\frac{56\,P}{100}$.

Pounds of oil produced from one gross bushel

$$=Z\div\left\{\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)\right\}.$$

Pounds of oil in cake $=.56\,P-Z\div\left\{\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)\right\}.$

Percentage of oil in cake

$$=100\,\frac{.56\,P-Z\div\left\{\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)\right\}}{Y\div\left\{\left(Z+Y-\frac{XY}{100}\right)\left(\frac{1.79}{100-W}\right)\right\}}. \qquad (5)$$

For the exemplifying values, $C=22.40$, $W_0=14$, $N=240$, $O=.40$, $K=.10$, $B=1.00$, $V=3.4$, $X=8$, $W=8$, $F=4.00$, $P=38$, we have, from formula (4),

$$33.6\,H+.0325\,Z-.0190\,Y-4.00. \qquad (6)$$

From formula (5) we similarly obtain as the percentage of oil in the cake,

$$100\,\frac{21.28-Z\div\{.0195\,Z+.0180\,Y\}}{Y\div\{.0195\,Z+.0180\,Y\}}. \qquad (7)$$

To check these formulas, we may take $H = 1$, $Y = 3360$, $Z = 1800$, when we have, as the profit per hour, $24.39, the test of the cake being, from formula (7), 6.98 per cent.

Formulas (4) and (5) are of perfectly general application to any standard-process crushing mill which runs its impurities through with the seed, and enable any manufacturer who accurately knows his costs, and can experimentally determine his possible relations of output and yield, to fix upon that method of working which will return to maximum profit.

CHAPTER XI.

COST OF PRODUCTION.

Classification of operating expenses.—Separation of non-comparative items.—Grouping of special accounts.—Their analysis.—Freight and drayage on oil.—Daily reports.—Specimen results.—Ideal figures.—Frequent shutting down of linseed mills.—Labor required for operation.—Cost of press cloth.—Programme of operation in five typical mills.—Other costs than those of mill operation.—Records of cost.—Figures to be used in calculating cost of oil.—General analysis.—Wages paid in linseed-oil mills.

The moment we begin to compare the record of one linseed-oil mill with that of another, we find such differences in the conditions of operation that the results of the comparison are confusing. Take a western mill producing bulk raw oil only, which it ships east in tank cars. Its expense per gallon of oil made, or per bushel of seed crushed, is naturally much less than that of some other mill producing various grades of refined oil which it ships largely in barrels. We have already given data for eliminating differences in operating condition in comparing yields of oil. We now discuss the reduction of comparisons of manufacturing cost to a true competitive basis.

The following is a general classification of the operating expense of a linseed-oil mill, not including the general executive or selling expense nor the cost of material (i.e., flaxseed):

PLANT.

Insurance.	Miscellaneous expense.	Superintendent.
Taxes.	Repairs.	Watchman.
Lighting.	Press mats.	Filter cloth.
Office expense.	Press cloth.	

STEAM.

Fuel.	Firemen.	Boiler and engine repairs.
Water.	Helpers.	
Engineers.	Handling coal and ashes.	

LABOR.

Foremen.	Temperers.	Trimmers.
Pressmen.	Rollmen.	Filterers.
Molders.	Cloth sewer.	Seed cleaners.
Strippers.	Truckers.	Elevator men.
Miscellaneous.	Shipper.	

SPECIAL ACCOUNTS.

1. Packers.
2. Cake grinders.
3. Teamsters.
4. Freight and drayage.
5. Coopers.
6. Fillers.
7. Barrels and cooperage supplies.
8. Drier.
9. Boiling and refining labor.
10. Filterers for special oils.
11. Bags.
12. Refinery supplies.

The separation of the "special accounts" from the others given forms the basis for an intelligent comparison of the cost of operation. Item 1, packers, would be properly included under "labor," if it were not that some mills grind their cake. Bags (11) would be similarly treated. Cake grinding (2) includes all labor for grinding and bagging cake. This is properly chargeable, not against the expense of crushing seed, but, together with the cost of meal bags (11), against the premium obtained for meal. If, then, we compared a mill grinding all of its cake with one grinding no cake, we should have in the latter case a considerable item of expense for packers (1), for which there is no correspondingly heavy item in the former case. The proper procedure is therefore to eliminate the item 1 from the crushing cost, deducting it, instead, from the gross price realized for the cake. Items 3 and 4 vary widely with market conditions at various points. They are related, not to the expense of crushing seed, but to that of marketing oil; they enter into consideration whenever a price is quoted on oil delivered to the consumer; and they should therefore be deducted from the price realized for oil. Items 5, 6, and 7 are expenses incident to barreling oil. They should be charged, not against the cost of crushing seed, but against the increased price realized for oil in barrels. Items 8, 9, 10, and 12 should similarly be charged against the premiums realized for special oils. With these eliminations the charges under plant, steam, and labor form a proper basis for the comparison of costs in old-process linseed-oil mills. They represent the "elevator to tank" expense, or that necessary to place oil in tanks from seed delivered at the mill elevator.

Items grouped as "special accounts" should, however, be carefully analyzed with the same strictness that characterizes the analysis of manufacturing costs proper. Too many crushers group them and try to ignore them. They may be classified as follows:

1. Barrels, including supplies, cooperage, and filling.
2. Bags and freight on cake and meal, including cost of grinding cake.
3. Freight and drayage on oil.
4. Boiling and refining, including special filterers, supplies, and drier.

The above charges are not made against the seed crushed, but simply as a general charge against the commercial operation. It would be a very simple matter to classify vouchers to the above accounts. The information thus obtained would be of value if the crusher would apportion the charges, not against the number of bushels crushed, but against the work actually done. For instance, barrels, cooperage, and labor employed for filling should be figured to so many cents per gallon of oil in barrels; bags, grinding cake, freight on cake and meal to so many cents per ton of cake; boiling and refining to so many cents per gallon of oil treated; freight and drayage to so many cents per gallon of oil shipped. Most mills possess practically all of the information necessary to obtain such figures, the only change required in order to record then being that these special account items be reclassified and charged to the particular account for which the money is spent.

One reason why such a course should be taken is that unless this is done these general accounts form a convenient dumping ground for all sorts of charges, and enable a dishonest manager or a careless accountant to obtain an apparently very low "manufacturing expense" which does not represent the conditions of the mill operation to the slightest extent.

The profitable operation of a mill depends upon all expenses, from seed at Duluth or other primary market to oil delivered to the customer and cake finally disposed of. A large item included within these limits is that of freight on oil. Obviously, other things being equal, the more oil freight there is to be paid on shipments from a particular mill the less profitable is the operation of that mill, and in order to compare the entire operation of one mill with that of another we must know how the amounts of freight paid on oil shipped compare. In order to know this, all freight and drayage charges on every gallon of oil sold must be referred against the price realized. This can be done very simply and readily on shipments direct from the mill to a customer and, with a little more complication, on shipments from a mill to a tank station and then to a customer. The only complication that will come in will be where a tank station is receiving oil from two or more mills, in which case care would have to be exercised to see that any freight from the station to the customer is figured against the proper mill. In most cases this could be determined by considering

the kind of oil shipped. A tank station is not apt to carry the same kind of oil from two different mills, but where it does carry, for instance, raw oil originating from two or more manufacturing points, it is necessary to figure the total amount of raw oil shipped in to the station from each manufacturing point over a given period, and from that to compute what proportion of the freight on any particular shipment of raw oil from the station to a customer shall be charged to each mill.

Every selling station, whether a manufacturing point or not, obtains a certain average price for oil sold. This average price depends on many factors, some of which, if not most of which, also affect the cost of operation of the station. For instance, by undergoing certain expenses for traveling a salesman might secure an additional cent per gallon for his oil. In order to have an adequate appreciation of what this increase in average price means we should have with it a statement of the expense undergone in order to obtain this higher average price. Similarly, freights paid on oil should be shown as against the average price obtained. If oil delivered at Jacksonville returns two cents more than oil f.o.b. Richmond, that additional two cents obtained should only show in the average price obtained for Jacksonville sales on the condition that the freight paid on this also shows against Jacksonville sales. It therefore becomes necessary to have a second classification of all oil freight expense as against that selling station or office which obtains credit for the price applying to the particular sale in question. There is no difficulty involved in such classification.

The most serious complication is that every freight voucher must be classified in two different ways. This is handled without risk of interference by having the accounting department keep one set of the records and the transportation department the other.

Adopting the plant, steam, and labor items as those properly to be regarded as manufacturing costs chargeable against output, we readily arrive at intelligent comparisons. These are necessarily based on the seed crushed, since the product consists of two materials. Cost of operation must therefore be considered along with yield of oil. The necessary information for a daily knowledge of the economy of operation is then as follows:

(1) Seed crushed, in gross bushels.
(2) Impurities in seed, per cent.
(3) Seed crushed, in net bushels.
(4) Oil made, gallons.
(5) Cake made, pounds.
(6) Per cent of oil in cake.
(7) Coal burned, pounds.
(8) Number of employees, classed under "labor," with aggregate "labor" pay-roll.
(9) Yield of oil = $7\frac{1}{2} \times (4) \div 3$, or $7\frac{1}{2} \times (4) \div (1)$ if "working net."
(10) Labor per bushel = $(8) \div (3)$ or $(8) \div (1)$,
(11) Coal per bushel = $(7) \div (3)$ or $(7) \div (1)$.

The last three items give all the information that can readily be obtained daily. The bushels crushed per man employed varies all the way from 20 to 120, making item (10) vary from \$.05 to \$.0083. Under more carefully supervised operation, the "labor" cost per bushel has varied in one case from \$.0193 to \$.0216; in another from \$.0173 to \$.0216; in another from \$.0205 to \$.0238; in still another from \$.0182 to \$.0190. An average figure is \$.02; and if the average wage is \$12.50 per week of 72 hours, each man should produce 625 bushels weekly or 104 bushels daily, say in round figures, 100 bushels. Figures as to yields have been given elsewhere. The coal consumption is usually much higher than it should be, since not a half-dozen linseed-oil mills in the country have power plants that can be considered in any sense economical. Fluctuations have been observed in item (11) of from 4.32 to 12.40. The best plant averaged about 6.00. The corresponding fluctuations in cost of "steam" are from \$.0072 to \$.0193 per bushel, with an average of about 1 cent. The "plant" items are more variable, especially that of repairs. Insurance and taxes are usually subclassified. The remaining items are principally press cloth, the average cost of which is not far from one-half cent per bushel, and repairs. The total of the remaining items may be kept down to about 1 cent per bushel, including press cloth and repairs, providing this last item is understood to include running repairs only (chiefly roll grinding, packings, and labor) and not additions or replacements of machinery. Rough figures for plant, steam, and labor expense per bushel of seed crushed under the best operation are therefore 1, 1, and 2 cents, or a total

of four cents. At many mills the cost is 50 per cent, or even 100 per cent, in excess of this. Much depends upon the speed of operation of the presses. One crusher, who practices rather rapid operation, consumed at various periods from 104 to 208 bushels of seed per press per day, the yield varying from 19.80 in the former case to 19.42 in the latter.

Linseed mills are frequently shut down. In the earlier days of the industry, when speculation in flaxseed constituted its leading feature, such shut-downs were sudden, frequent, and sometimes protracted. At present they occur less often, but still they do occur.[1] At such times a certain amount of expense is undergone which can be logically charged only to manufacturing expense. Such expense includes the watchmen, lighting, power, the cost of shipping oil, etc. In four mills the "manufacturing cost" while out of operation ranged from $1000 to $2000 per month, from 1 to 10 tons of coal being burned per day. Much of this coal was no doubt more properly chargeable against boiling and refining expense, but it is not customary to attempt the subdivision of power costs against special accounts. When a mill is permanently closed and its seed, oil, and cake shipped out, the expense of maintenance of the property may be reduced to practically nothing, or just sufficient to comply with insurance requirements. Costs of cooperage and of boiling and refining are given elsewhere, as are data regarding the cost of grinding cake. A mill in operation usually requires a superintendent, from 1 to 10 repair men, and 1 or more watchmen. One foreman is required, in the mill proper, on each shift of 8 to 12 hours; the 12-hour shift is far more common. He is assisted, in larger mills, by a temperer, who attends to the heaters, the supply of foots thereto, etc. One man, with help within call, can attend to from 12 to 18 stands of rolls. The press gang, in standard practice, consists of three men for each group, pressman, molder, and stripper. One man can more than mend the press cloths for the largest mill. With automatic trimmers, one man to each machine is ample provision. One filterer, with a helper, can filter all the oil produced in the largest mills, and in smaller mills these same men fre-

[1] This condition happens to be vividly represented by the figures for oil-cake exports and receipts from the port of New York by months. Since cake is not stored for any great length of time, the exports and receipts represent fairly closely the operating condition. New York receives oil cake from Buffalo mills, and exports, in addition to the Buffalo cake, its own product.

quently make the special oils. The expense of handling seed depends entirely upon the arrangement of the equipment. With automatic packers, two boys and one man can pack, sew, and truck to the scales all the cake that one machine will handle. The cost of labor for firing boilers averages not far from 50 cents per ton of coal.

Press-cloth costs are apt to fluctuate widely owing to the intermittent cutting of new cloth. These fluctuations may be avoided by inventory of cloth in use, as well as new cloth, in proportion to its estimated value, when preparing monthly statements.

The following is a summary by days of the condition of operation at five mills during one year, showing some of the factors which result in intermittent activity in the oil business:

OPERATION BY DAYS DURING ONE YEAR.

Mill	1	2	3	4	5	Total
Closed permanently	....	....	....	....	313	313
Closed, market conditions	213	162	57	39	....	471
Closed for construction	....	3	5	22	....	30
Closed by breakdowns	....	1	....	....	....	1
Closed by labor troubles	7	....	....	....	....	7
Closed by holidays	1	1	2	3	....	7
Closed by transportation conditions	....	7	....	18	....	25
Total days closed	221	174	64	82	313	854
Ran at part capacity	....	....	146	....	....	146
Ran full capacity	92	139	103	231	....	565
Total days run	92	139	249	231	....	711
Grand total	313	313	313	313	313	1,565

Percentage of full operation, 48.

With the mill "working cost" of 4 to 8 cents per bushel, the actual cost of operation has only begun. Thus, in one example, the monthly cost of barreling exceeded the entire working cost; freight and drayage amounted to half the working cost; executive and selling expenses equaled the working cost. It is these items, which must all be considered in arriving at the cost of oil, that lead manufacturers to speak of the working cost as from 15 to 30 cents per bushel, rather than from 4 to 6 cents per bushel. As we have tried to show, the former costs include items which are not properly chargeable against the production of bulk oil. The logical method for the crusher to pursue is to set his price for bulk oil at such figure as is indicated by the "plant," "steam,"

and "labor" working costs, plus any general and undivisible executive and selling expense, the expenses for cooperage, boiling, refining, freight, drayage, cake bags, and cake grinding being estimated for each particular instance. In one mill, which crushed 651,332 bushels on 12 presses during the year 1896, making 8/6 and 7/6 changes per hour, a very good output even for a new mill, the costs per bushel were classified as follows:

Interest and discount	$ 0155
Miscellaneous expense	0062
Fuel	0066
Labor	0245
Insurance	.0024
Executive and selling	0125
Barrels	.0278
Cake bags	0091
Meal bags	0014
Drayage	.0008
Supplies	.0015
Taxes	0014
Press cloth	0032
Total	$ 1124

Of this total, at least $.0386 was properly chargeable against special accounts, leaving $.0738 as the working cost to be used in arriving at the price of oil. In another mill the corresponding total cost ranged, during nine successive years, from $.1107 to $.2753 per bushel, the high figure being due to expenses for construction charged against operation; the average under usual conditions ranging from 16 to 18 cents.

Since the dates of the statements given, costs of labor and materials have widely changed; yet with improved methods of operation it is probable that the total cost of producing bulk oil and cake from seed delivered at the mill averages well under 8 cents per bushel. Crushers may use a figure approximating this, or a 20 to 30 cent cost, representing every expense of whatever nature, in arriving at a price for their oil; but if the latter figure is used, the price of oil will be one at which oil in barrels will be sold too cheaply, oil in tanks will be quoted too high, consumers will not pay their proportion of freights, and the cost of producing special oils will improperly affect the price of raw oil. This is not good business.

Knowing the working cost, then, as defined in one way or the other, we have only to add it to the cost per bushel of seed delivered at the mill, to subtract the revenue derived from the cake, and to divide the remainder by the oil yield in gallons, in order to obtain the cost of the last. Or,

If B = cost in dollars of one bushel of seed, f.o.b. mill,
W = cost in dollars for working one bushel of seed,
C = pounds of cake produced per bushel of seed worked,
O = pounds of oil produced per bushel of seed worked,
K = value of cake per ton of 2000 pounds, f.o.b. mill,
x = cost of oil per gallon of $7\frac{1}{2}$ pounds,

$$x = \left(B + W - \frac{CK}{2000}\right) \div \frac{O}{7.5}\,.$$

The table in the appendix shows the cost of oil thus calculated for various prices of cake and seed, and working costs, assuming a production of 19 pounds of oil and 37 pounds of cake per bushel. Such tables are largely used by crushers for checking their more accurate calculations. The assumed yield of oil is of course on the conservative side.

The average wage paid in linseed-oil mills for the semi-skilled labor employed in the mill proper is generally from \$11.00 to \$14.00 per week, or say from 15 to 20 cents per hour. In three mills the average rates for "labor" as classified in this chapter were \$11.51, \$11.77, and \$12.53, respectively, per man per week. In one 10-press mill the force numbered from 31 to 33 men, crushing nearly 2000 bushels daily, including manager, superintendent, machinist, general laborer, two to four men on cars, etc., and the following men on each 12-hour shift: one engineer, two pressmen, two molders, one stripper, one trimmer, one temperer, one fireman, one and one-half packers, one elevator man, one cooper.[1]

The careful accounting for material is of more importance than the record of costs of operation, since the cost of the seed itself represents from 75 to 85 per cent of the value of the finished product. The seed is handled as a cash item, but the account is kept in a special ledger. The unit is the bushel of 56 pounds, or the 56th fractional part of a bushel. The clean seed and impurities are separately recorded.

[1] Statistics of average wages paid in linseed-oil mills may be found in the nineteenth annual report (1904) of the United States Commissioner of Labor.

CHAPTER XII.

OPERATION AND EQUIPMENT OF TYPICAL MILLS.

Most mills properly subject to criticism.—Details regarding the mill illustrated in Fig. 1. —An 84-press mill.—Its equipment in detail.—Excessive roll equipment.—Low number of plates per press.—Unusual grouping of presses.—Rolls on second floor.—Power equipment.—Tide-water location.—Evolution of trimming methods.—Various methods of operation.—Auxiliary buildings.—A 40-press mill.—A 15-press mill.—A 10-press mill.—A 12-press cake-grinding mill.—One of the older mills. —Old-style change blocks.—Methods of operation.—A 50-press mill.—Defective arrangement.—Grouping of presses.—Various methods of operation.—Hydraulic system.—Power plant.—Inadequate roll equipment.—Hydraulic operation.—A typical tank station.—An English mill.—Proper power equipment for a linseed-oil mill.

A PRELIMINARY description of the usual equipment of linseed-oil mills has been given in Chapter I. More detailed information regarding the machinery is presented in the chapters describing the various operations of oil crushing. We now consider some typical mills, with particular reference to the arrangement of the departments with respect to economical operation. Much adverse criticism may be expected, since most linseed-oil mills represent the results of gradual growth and are in no sense what the original builders intended they should be, or what the present owners would like them to be.

The mill illustrated in Fig. 1, facing page 9, may be regarded as a good example of modern installation, having been recently built and not being the outgrowth of a smaller mill. In plan this mill forms a rectangle, one story high, the power and hydraulic equipment being in the upper left-hand corner, the press room in the upper right-hand, and the cake room occupying the entire lower half, excepting for a few oil-storage tanks in one corner, where the filling of oil is done. The seed elevator and storage tanks are adjacent to the corner containing the power equipment. Seed and coal are received from the river, and side tracks run on two sides of the mill. The one-story construction and the comparatively open press room are desirable features; the lack of provision for storage of cake in large quantities is unfortunate.

Fig. 47 shows the general arrangement of buildings at one of the largest mills in the country. This contains 84 presses in 12 sets of 7 each, having an aggregate of 1383 plates, 36 stands of 5-high 14 by 48 inches single-belt idler-drive crushing rolls, 12 2-high 72-inch heaters, 12

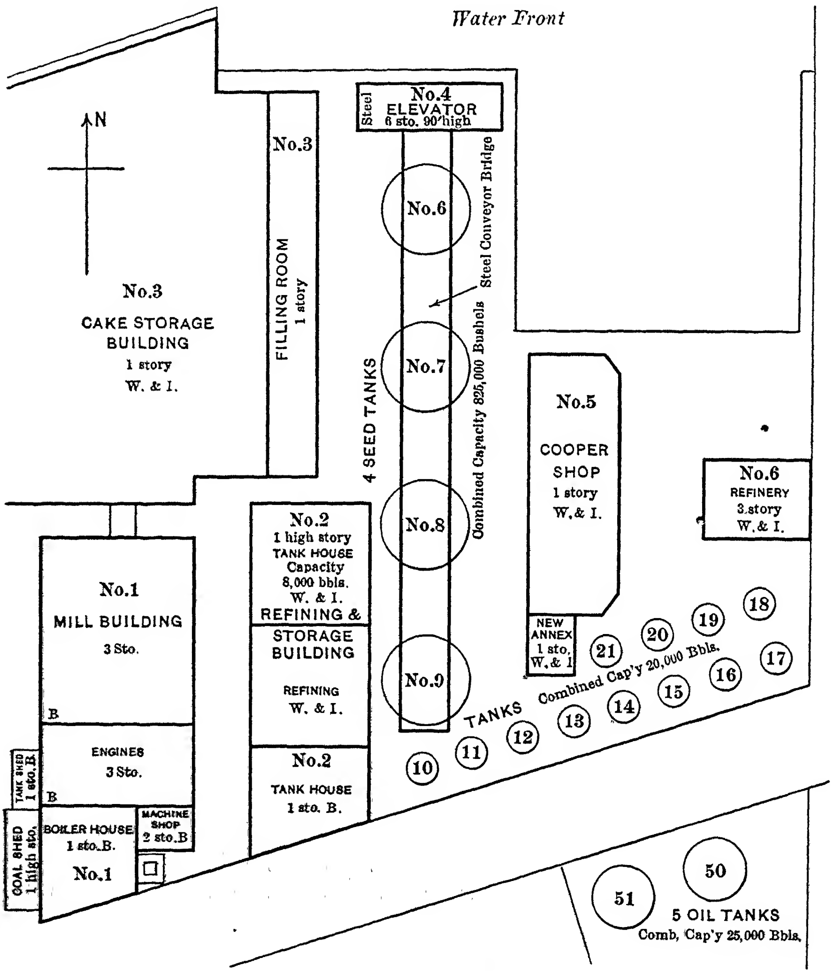


Fig. 47.—84-Press Linseed Oil Mill at Tidewater.

double hydraulic cake formers, 8 4-crank belt-driven hydraulic pumps, and 2 pairs of 20-ton accumulators. Power is furnished by four water-tube high-pressure boilers, which supply one 18 and 36 by 48 inches Hamilton-Corliss tandem compound condensing engine at 81 r.p.m.,

which drives the main mill; one 24 and 14 by 24 inches Westinghouse vertical cross compound condensing engine at 280 r.p.m., which operates the elevator and the conveying machinery from the seed tanks to the mill, and one 9 and 15 by 9 inches Westinghouse vertical cross compound engine driving a 40-kw. lighting generator. The engines are surface condensing. A 1000-gallon Underwriter fire pump is used. A good machine shop is provided as an auxiliary to the power department. This contains one 20 inches by 10 feet engine lathe, one 15 inches by 6 feet engine lathe, drill press, emery grinder, power pipe cutter (2½ to 6 inches), etc. A small generator, driven from the main line shafting, illuminates the mill during the day, permitting of shutting down the larger lighting unit. The main mill building (No. 1) is a three-story structure, 73 by 85 feet, built in 1867–68. It has stone and brick outer walls and interior timber construction of spruce and white pine. It originally constituted the entire mill, the press room being at the south end, and the balance of the building being used for cake and oil storage. At the present time the seed cleaners and storage bins occupy the top floor, the second floor contains the rolls and the ground floor the presses. This arrangement is bad, subjecting an old and rather light building to enormous weight on its top and second floors. The seed bins alone hold 12,000 bushels, or 336 tons. The building is so wide that intermediate posts were necessary between the side walls. Two intermediate rows of such posts were installed, the space between them being unused on the top and second floors, and occupied by the cake trimmers on the first floor. Between each two rows of posts and the two corresponding outer walls there were placed, on the first floor, two lines of 21 presses each, with six heaters between the two lines the formers standing adjacent to the heaters; on the second floor two lines of 9 roll stands each, and on the top floor two compartment bins holding 6000 bushels each. Each bin is supplied by an 88-foot length of 15-inch iron-cased screw conveyor from the four Huntley sifters or seed cleaners and their wooden discharge elevators.

As the rolls are above the heaters, no elevators are required between the two. Screw conveyors carry the meal from each three rolls to their proper heater. A system of gratings and screw conveyors under the press-room floor carries trimmings, sweepings, etc., to two central points, from which two elevators raise them into two of the heaters. It would be better if this material were distributed among all of the

heaters. Foots are cared for in iron drums until delivered to the heaters.

The excessive number of rolls in proportion to the number of presses may be justified by the advantage of having one of the three stands of rolls provided for each set of presses in reserve for grinding. A less justifiable peculiarity is in the small number of plates per press, the average being only 16.5. This results, of course, in a small output per press. It was due to the fact that many second-hand presses were available at the time the mill was reconstructed, as a result of the discontinuance of operation at some other mills. The grouping of the presses in sets of 7 was unusual. There happened not to be room for four sets of 6 in the row; the number of presses available was ample; and it was thought that the additional press in each set, by giving a longer interval between pressings with a given number of changes per hour, might favorably influence the yield of oil. An equally good yield with an immensely greater output might have been obtained by a better arrangement of the presses and an increase in the number of heaters.

The three-story construction with a consequently low press room made the latter a disagreeable place on account of poor ventilation. At the same time it was frequently draughty and several sets of presses were uniformly subjected to the detrimental influence of cold blasts of air.

The location at tide-water offered both advantages and disadvantages. It facilitated shipments and receipts, of course. Seed, coal, and empty barrels were received direct from boats or barges towed by the company's lighters; oil cake and oil were sent out similarly in its owned or chartered bottoms. The expense of loading shipments varied, of course, with the rising and falling tide. A water-front location always leads to some small losses from petty thieving.

The trimming at this mill, after abandoning hand work, was originally done by automatic trimmers located in the press room, from which the cake was trucked to automatic packers in the cake house. Later on, both trimmers and packers were placed in the cake house. This led to delays in trimming, reabsorption of oil from the untrimmed edges by the cake, and a heavy loss of oil while the cake was in transit from press to trimmer. Finally, the trimmers were located in the press room, and as there was no room for the packers in that location, a link

belt conveyor carried the trimmed cakes to the packers in the cake house.

This mill has operated at various outputs, varying, probably, 100 per cent, with various methods of operation. It has been run at half capacity (42 presses), as a 63-press mill, and as an 84-press mill. The changes per hour have been, usually, six or seven; and at one time six changes were made on five presses of each set, the remaining three groups of two presses in each set on each line forming a fourth set, operated by a gang of men who moved from one to the other, drawing their supply of meal from each of the three heaters in turn, and forming the cakes on the spare sides of the three double formers. This arrangement put the output up to the maximum which the mill ever obtained, though still less than a good output from modern 18 to 20 plate presses; but it involved endless confusion, complication, and annoyance.

The shipping and filling room contains four direct-acting steam pumps for oil, one rotary oil pump driven by a vertical steam engine, and one air pump for the sprinkler system, besides the usual outfit of scales, all in an iron-clad frame building 32 by 165 feet, one story in height.

The cake house contains eight iron oil-storage tanks on the side adjacent to the filling room, the engine for unloading coal, and three scales of one-fourth, 2, and 10 tons capacity respectively, in a building 104 by 186 feet. This house also contains the cake-grinding equipment, including a Williams D36 grinder of 90 tons nominal daily capacity, an 80 horsepower motor, a wooden elevator carrying the ground product to the overhead 42 inches by 16 feet screen, and an iron-enclosed screw conveyor which delivers the screened meal to the storage bins.

The three tank storage houses are respectively 52 by 63 feet, 40 by 55 feet, and 38 by 46 feet in size. The last is three stories high, the others one story, with high ceilings.

The refinery is an iron-clad frame building 51 by 50 feet, two story. The arrangement of buildings is fairly good, considering the fact that the plant is a reconstructed one. The power equipment is properly located, and coal received at low cost by an overhead automatic railway, the car of which is fed by a hoist boom taking coal from boats. The automatic railway discharges into a coal-storage house 21 by 54 feet and 40 feet high, from which coal is chuted directly into the

charging car running on tracks in the boiler room. A 4000-pound Fairbanks scales serves to weigh the cars of coal. Seed passes quite directly from storage tanks to mill building. The latter has three exposed sides, while the cake house amply profits by the water front. Space for empty barrels, with a dock for their receipt, is convenient to the cooper shop, and the latter delivers barrels by a straight runway to the filling room.

Brief data regarding other mills may be of interest. One mill operates 40 presses of 24 plates each. The presses are in groups of 10, and 12 pressings per hour are made on each group by 6 men. The cake, which weighs 12 to 13 pounds, has been found to contain a high percentage of screenings. A large proportion of the cake is ground. These presses have too many plates, 20 being about the maximum number that men can readily handle. The making of $\frac{12}{10}$ changes per hour is practically equivalent to $\frac{6}{5}$, rather faster operation than is generally practiced, but not necessarily detrimental to the yield.

An old mill in Chicago contains 15 presses in 3 sets of 5 (five was once a popular number for a set), 3 heaters, with the auxiliary machinery, driven by a 200-horsepower engine, and supplied with steam from 2 horizontal boilers. This mill is not now in operation. It formerly crushed, with its 212 press plates, 1750 bushels daily. Its oil-storage capacity was 616,000 gallons, seed storage 200,000 bushels, and cake and meal storage 1200 tons; corresponding to operation for 140, 114, and 38 days respectively.

A now dismantled Eastern mill, equipped with 10 bare-plate presses containing 23 plates each, crushed the high daily average of 2000 bushels. It held 375,000 gallons of oil, 300,000 bushels of seed, and only 75 tons of cake. The building was arranged on a rectangular plot, the long east side paralleling the railroad switch. The seed elevator was at the northeast corner, the diminutive cake and meal room next, and then followed the mill building proper to the south. This comprised the boiler house and engine room on the east, with the press room on the west, the two being flanked on the north by the roll room. The presses were in two groups of 5, each served by a heater and former. Small storage buildings were located in the southeast corner of the yard, and the cooper shop in the southwest corner. The oil house (inside tank storage and filling room) was in the center of the plat. Outside oil tanks lined the western fence. There was ample

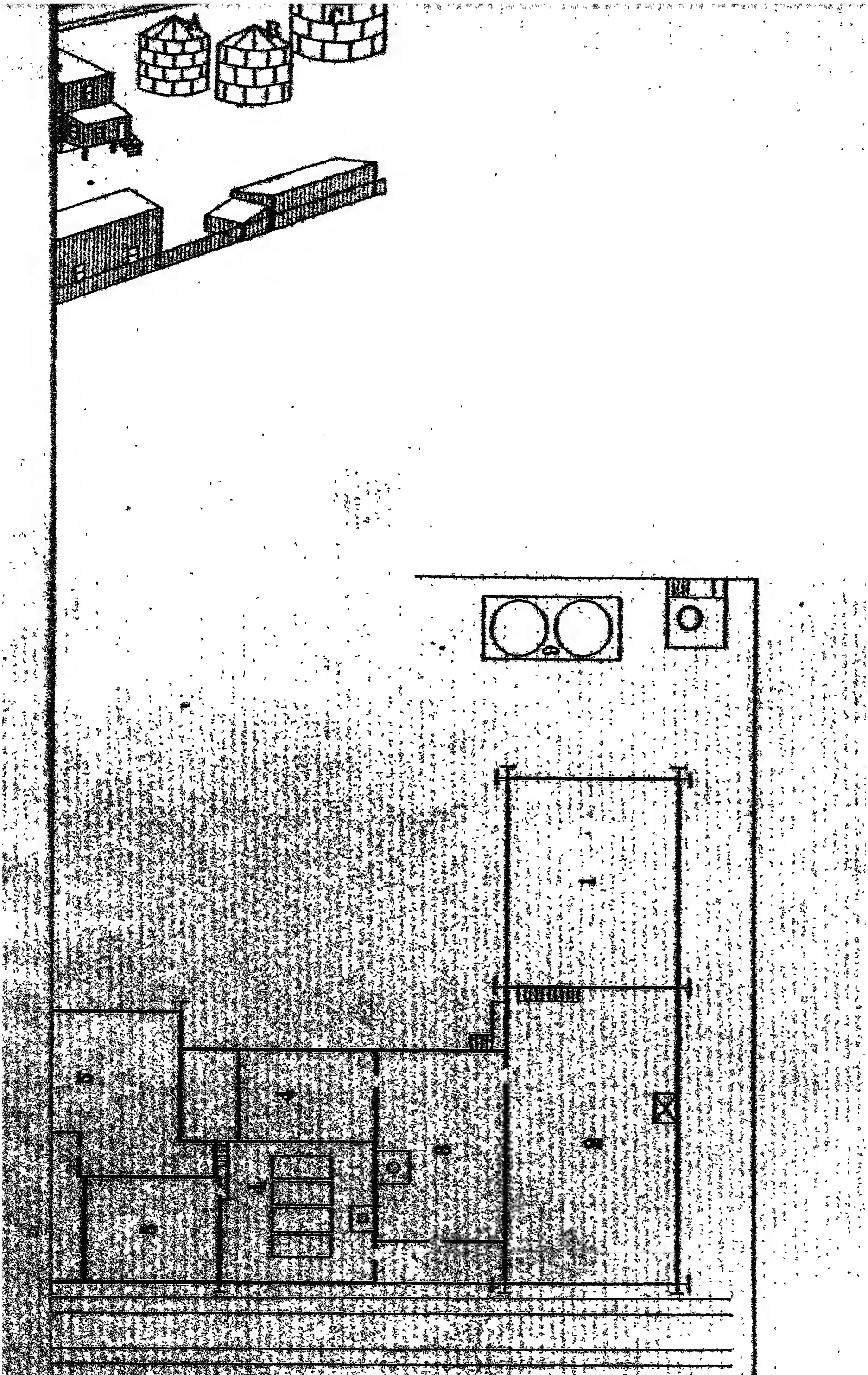
room for more cake storage, but practically all of the cake was ground. There were 4 stands of 48-inch 5-high rolls, a 95-horsepower Buckeye engine, two horizontal boilers, and two Lawther geared hydraulic pumps running at 33 r.p.m. Two high-pressure and one low-pressure accumulators were employed. The heaters were the 72-inch size, two-high. A single filter press, having 29 30 by 30 inches square plates, was used. Besides the outdoor tank storage and that in the oil house several small tanks were located in the basement of the main mill building. Hydraulic formers were used, with frames 12½ by 23½ inches, inside. Trimming was by hand. The old-style hydraulic control, with a nest of hand change valves in one block for the entire set of 5 presses, was used.

Another mill, which grinds all of its cake, contains 12 presses in 2 sets of 6 each. Ten are 19-plate Buckeye presses and two are 16-plate Callahan. Double mats, 17 by 37 inches, and 14-inch camel's-hair press cloth are used. The trimmed cake measures 12½ inches by 31¼ inches, and weighs 12½ pounds. Four 5-high stands of rolls running at 110 r.p.m. grind the seed. The heaters are 3-high, 72 inches. Double hydraulic formers are used, and a rotary trimmer. All of the cake is ground in a bar grinder running at 1400 r.p.m. Two filter presses are used, practically for raw oil alone, one having 29 32-inch square plates, the other 34 30-inch square plates. The storage capacities are: seed, 165,000 bushels; oil, 700,000 gallons; meal, 3000 tons. The hydraulic pumps are the old Lawther geared power-driven type, making 88 r.p.m. at the pinion shaft. Power is supplied by two 72 inches by 16 feet horizontal boilers, operating at 90 pounds presssure. The mill is driven by a 16 by 32 inches Bass Corliss engine at 81 r.p.m. It has crushed 2400 bushels of seed daily, but averages less. The arrangement of the buildings is on a rectangular plot, the north side fronting on the street, while one track enters from the west, traversing the center of the plot, and another, from the south, separates the mill building proper, on the east, from the cake house on the west. The power apparatus is at the north end of the one-story mill building, the seed elevator and seed-storage tank at its south end. The oil house is on the south side of the plot, midway of its length in an east and west direction. Scales are used to weigh the seed between storage tank and mill. Barrel storage is in the basement of the oil house, on the main floor of which the coopers are located. Three men are used on

each of the two press gangs, with one spare man to do all of the trimming. Two men mold cake on the double formers, while the third man fills the presses. When the press is filled, one of the molders strips the cakes which have been withdrawn while the other sweeps up. This is a rather more liberal allowance of labor than is customary. Two 12-ton accumulators are used, the pressures carried being 3750 and 500 pounds. The presses have automatic change cocks, and lifts are applied to the upper 5 plates. The press cloth is the Perkins 61a diagonal weave, weighing 2 pounds per yard. The arrangement of the press room is as follows: accumulators in the northwest corner; rolls along the east side, with supply bin overhead; rotary trimmer on the west side, with trough for sliding cakes from the two sets of presses. The presses and heaters are arranged in two groups symmetrically with respect to the east and west center line of the building, the rows of presses being nearest this center line and paralleling it, and the heaters set back of the presses toward the north and south walls.

Fig. 48 gives the plan and perspective views of a mill which has been more or less continuously operated since 1879. It contains 20 presses. Seed is received from Buffalo by rail, and is delivered from the storage tank, as required by the mill, by means of the screw conveyors shown. The elevator is in the center of the tank, and is of course housed in. The seed bins are on the second floor of building 6, the rolls on the first floor, driven from a jack shaft in the basement, directly operated from the main engine in building 5. The presses are located along the north and east walls of building 5, forming an L-shaped arrangement. The four heaters form a second L, inside that made by the presses, three of them forming its long north side and two the shorter east side. The rolls are in three rows of three stands each. The trimmer is in building 6, just west of the press room. In the southeast corner of this portion of building 6 are the hydraulic pumps, a most inconvenient location. The press room is one-story, as it should be, but is low and has practically only one exposed side. The seed-storage capacity is entirely inadequate for a mill depending upon rail transportation alone for its supply.

The nine stands of 5-high rolls include 4 16 by 60 inches, 1 20 by 60 inches, 10 14 by 54 inches and 30 14 by 48 inches chilled-iron rolls, ample equipment for the press capacity. The heaters are 72-inch, two-high, with open tops. The three hydraulic pumps are the Lawther duplex



furnished for the entire room, to truck the cakes to the trimmer. Eleven men thus made 1.2 changes per hour. The relative labor expense was therefore less when making $\frac{6}{5}$ changes, while the yield of oil should have been the same, so far as the time interval may have been expected to affect it.

One of the most poorly arranged mills in the country, while at the same time one that produces exceptionally good results in yield of oil, started some years ago as a 20-press mill. It now contains 50 presses and is of course badly crowded. It has 960 plates, or an average of 19.2 per press. It stores 530,000 gallons of oil, 2,500,000 bushels of seed, and 1620 tons of cake and meal. The press specifications are as follows:

Five have 18 plates each, no lifts, and double hair mats.
Fifteen have 18 plates each, lifts, and single hair mats.
Twenty-eight have 20 plates each, lifts, and single hair mats.
Two have 20 plates each, lifts, and single hair mats. These two are not usually operated.

The mats are 16 by 36 inches, weighing $7\frac{1}{2}$ pounds. The press cloth is the Perkins 94P 16-inch heavy center, and runs five weeks without breaking.[1]

The mill is on an irregularly shaped plot, a four-story building at one end containing, from top floor downward, the seed bins, rolls, shafting, and press room. At the other end of the plot is the oil house, which accommodates coopers, fillers, and tanks; while between is the cake house. This has one railroad frontage, as has also the oil house. Oil-storage capacity is entirely inadequate from a commercial standpoint. Seed storage is ample by reason of the presence of a modern elevator, owned by the crusher, on an adjacent plot of ground. The roll floor of the four-story building contains two lines aggregating nine stands and two longer lines aggregating sixteen stands of crushing rolls. A load of not less than 500 pounds per square foot is carried on this floor. The shafting floor contains cake elevators of the link belt type, by means of which the stripped cakes are carried up from the press room, a link belt conveyor taking the cakes from the elevators, and two French

[1] This heavy-center cloth is found in general practice to give results as to cost rather inferior to those found with the 61a, besides resulting in the production of a slightly lighter cake.

trimmers and packers. The press room proper, on the ground floor, has a low ceiling and three exposed sides, and is ventilated by a 48-inch blower. There are five rows of presses, ten in a row, with six heaters conveniently arranged in rows of two each between the first and second and third and fourth rows and between the fifth row and the wall, with two additional heaters awkwardly located as extensions of the first and second pairs referred to. The hydraulic pumps and accumulators divide with these two heaters the space along one side wall. The engine room adjoins the press room on one side.

The first and second rows of presses, totaling twenty and served by three heaters, afford two groups of seven and one of six. The third and fourth rows are similarly grouped. The fifth row has two groups of five, served by two heaters. The presses are thus grouped in sets of five, six, and seven. Usually seven changes per hour are made on the six and seven press sets, and six changes on the five-press set. This makes the average pressings per hour 1.08. Equal output is secured, at the unimportant cost of a reduced time interval on some of the presses, by not operating the single odd press in each of the four seven-press sets. More frequently, however, two of these odd presses are operated with the two five-press sets, thus giving a longer time interval on the latter, and the remaining two are discarded, this arrangement utilizing 48 presses in eight sets of six, making seven changes per hour. This would be unquestionably the best method of operating the mill if it were not for the extremely inconvenient location of some of the heaters and formers with respect to the presses. The hydraulic control is by means of the objectionable nests of hand-operated change valves. As these are in nests of five, two for each line of presses, their operation with press sets of six involves even more than the usual amount of inconvenience and hazard to the oil yield.

Power is supplied by high-pressure boilers. The mill is driven by a 300-horsepower Westinghouse vertical cross compound engine, a 19 by 48 simple Corliss engine at 60 r.p.m., and some smaller equipment. Horizontal independent jet condensers are used. An electric generating set furnishes light. Eight Lawther hydraulic pumps of the duplex geared type are used. The heaters are two-high, open top. The formers are Buckeye single hydraulic, with frames 12¾ by 32½ inches. Four filter presses are used: one 32-plate 30 inches square, two 33-plate 30 inches square, and one 29-plate 24 inches square. Two

18-ton high-pressure accumulators and one 12-ton low-pressure are used. A 13-pound cake is made, measuring, trimmed, $13\frac{1}{2}$ by 34 inches. This is packed in 29 by 50 inches bags holding 317 to 320 pounds. With the automatic French machines, 600 bags are packed per 10 hours on each packer. Automatic barrel fillers are used, 100 seconds being required to fill a barrel under gravity flow of oil. The worst feature of equipment is in the rolls. Only nine stands are of the proper type for linseed, being 14 and 16 inches in diameter by 48 inches long, running five-high and at 150 r.p.m. The remaining sixteen stands are three and two high flour-mill rolls, 9 by 24 inches, running 350 to 450 r.p.m., and are entirely too light. With such equipment it is difficult to see how even reasonably good yields can be obtained. A roll grinder is kept in constant operation, and the nine stands of linseed rolls undoubtedly work at abnormally high capacity.

The arrangement of the hydraulic system is as follows: there are eight pumps, two high-pressure, two low-pressure, and four combination high and low pressure. The two low-pressure pumps supply, through a small accumulator, the packers and formers. The remaining pumps discharge from the high-pressure cylinders through the two 18-ton accumulators to the presses. The low-pressure cylinders of the combination pumps discharge direct to the presses, no accumulator being employed. This is an injudicious omission, and the low-pressure on the presses varies from 350 to 750 pounds. Better results would be secured if a low-pressure accumulator were used and all the pumping equipment worked as one system.

A typical tank station consists of a rectangular building adjoining a railway siding, with outside oil storage in connection. One end of the building is used by the coopers, the other end for filling. The center of the building contains inside storage tanks. A shipper, an engineer, and a cooper operate the station. Automatic barrel fillers are employed and square five-compartment filling tanks hold the various grades of oil for filling.

A typical English mill at Boston, Lincolnshire, which crushes linseed among other seeds, produces, with linseed, a cake containing about 12 per cent of moisture and the same amount of oil. The cake is soft, as preferred by English feeders. Yields of 126 to 131 pounds per quarter (416 pounds) of Argentine seed and of 138 pounds per quarter (410 pounds) of Calcutta seed are claimed, corresponding to 18.8 and 17.2

pounds per bushel of 56 pounds. This, with a 12 per cent cake test, would make the percentage of oil in the seeds, respectively, 39.0 and 41.5, figures which, though high, are not unreasonable. Woolen bagging is used for press cloth, and is stated to cost not over 3½*d.* per ton of seed, or less than \$.002 per bushel. This is less than half the usual cost of press cloth in this country. The presses have malleable-iron plates, corrugated crosswise, without mats, the gap between the plates being 2¾ inches. The low-pressure hydraulic system operates at 800 pounds per square inch, and it is usual for the oil to start flowing slightly while in the former. Two men turn out 72 cakes per 40 minutes, weighing 10½ pounds each, trimmed. Each stand of rolls grinds seed for 72 plates. This would be considered too small an equipment in rolls in this country. With 12 per cent of moisture in the cake, there is a slight overrun in production on the usual seed; which confirms the analysis given in the chapter on Shrinkage in Production.

The ideal power equipment for a linseed mill is a subject permitting of extended discussion. Other factors than that of cheap coal govern the location of oil mills, but it fortunately happens that many desirable locations for a crushing establishment are at the same time points where fuel is comparatively cheap. It therefore follows that producer gas power, which depends for its advantage upon a relatively high price for coal, is rather less adaptable, in general, than steam power for the requirements of an oil mill. Steam has other advantages, also, which make it, other things being equal, more desirable than the more convenient form of power which may be purchased from outside for electric driving.

The main mill, comprising rolls, hydraulic equipment, heaters, trimmers, and packers, with the auxiliary machinery, runs practically 24 hours at a load almost uniform. It should therefore be driven by the most economical and reliable steam engine obtainable, preferably a horizontal cross compound of the detachable-gear type, which should be operated condensing. Electric light should be furnished by a direct-connected high-speed generating set. As this will operate at night only, it is not desirable to use its exhaust for heating, and it should consequently be also run condensing. The same argument applies to the separate engine which should be installed for operating the seed elevator. This last department should not be driven from the main engine, on account of its intermittent demand for power. It may be either

directly or electrically driven, according to its distance from the engine room. A small dynamo should be driven from the line shafting of the main engine to supply the small amount of light needed during the daytime, thus permitting the shutting down of the separate lighting unit through the day. Small outlying power requirements, such as those of the cooper shop, filling room, refinery, filtering room, may be supplied by either electrically driven or direct steam driven machinery, the latter being employed to a sufficient extent to furnish an adequate supply of exhaust steam for warming buildings, heating and boiling oil, and for heating feed water. The main mill, and the hydraulic pumps, if power-driven, should be directly driven from the jack shaft of the main engine, which should be located accordingly. Some electric transmission is in most cases necessary, and the necessary generator may be either direct-connected to the main engine, at the side of its fly wheel, or belted from the jack shaft. For engine economy, high-pressure boilers should be used. Oil pumps, if not steam-driven, may be either of the plunger or the rotary type, the latter being permissible where no close regulation of pressure is required. Ample provision for exhaust steam requirements must be made, else live steam will have to be used to meet such requirements. The steaming of the heaters, blowing out of filter presses, and the heating of oil for the processes of boiling and refining can all be done by exhaust steam. If the supply of the latter from outlying machinery is impracticable without long transmissions of live steam to such machinery, then it may prove best to use steam-driven hydraulic pumps. The vacuum system of circulation will prove more satisfactory than the common gravity return system. The boilers should be supplied by brass-fitted outside end-packed duplex heavy-pressure pumps, taking their supply from an open feed-water heater. To this heater should be led the condensed steam from the engines, drips from the exhaust system, and sufficient exhaust steam to raise the temperature to the boiling point; or an economizer may be used to supply feed water, in which case very much less exhaust steam need be provided, and the hydraulic pumps may in all cases be belt-driven. If hard coal is used for fuel, an insufficient chimney draft may be supplemented by a small forced-draft fan, which should be so operated as to produce practically atmospheric pressure in the furnace, and automatically regulated. With soft coal, ample combustion space should be provided. Mechanical stokers

will save labor when soft coal is used. About 10 horsepower per press of capacity represents the indicated horsepower to be developed by the engines under average conditions. The mill should have fire pump, hydrant, and automatic sprinkler equipment. The last may be the "dry" system in buildings like the cake house which are ordinarily not heated. The main mill building, containing the press room, will be sufficiently warm, when operated, in winter, without artificial heat.

CHAPTER XIII.

OTHER METHODS OF MANUFACTURING.

Wide application of the standard method.—The new process.—Reclaiming the naphtha.—Prejudice against the new-process oil.—Danger involved in percolation.—Comparative estimate of cost, new and old process.—Actual working cost.—Substitutes for naphtha.—High cost of steam.—Classification of labor.—Details of equipment.—The intermediate separator.—New-process meal.—Cost of buildings.—Other substitutes for the hydraulic press.—The Anderson oil expeller.—Report of tests.—Disposal of cake.—Advantages of the expeller.—Details of construction.—The oil produced.—Sundry considerations.—The Lawther automatic milling device.—European practice.

FROM 85 to 95 per cent of the linseed oil produced in the United States is manufactured in substantially the manner described in the foregoing chapters. The slight differences in method at various establishments involve modifications of operation rather than of equipment and are largely due to variations in commercial conditions.

An increasing amount of seed is being crushed by other than the standard or "old" process. Foremost among these new processes is that of percolation by a volatile solvent, as formerly practiced at Leith, Cleveland, Detroit and Toledo, and at present operated at Chicago in one large mill. In this last mill the seed is first coarsely ground in two stands of rolls, one a Lawther, 15 by 48 inches, the other a Callahan, 15 by 48 inches, both five-high and running at 200 r.p.m. It is then heated to a temperature of about 180 degrees in two large flat plate open driers, to drive off the moisture, and is carried into storage in the 16 overhead bins of 1000 bushels capacity each. From the bins, quantities of 1000 bushels at a time are dumped into the percolators, of which there are 16, 13 feet 6 inches in diameter and 14 feet high. The percolator, like the press in an old-process mill, measures the capacity of the works. Ordinarily the entire process of percolation occupies nearly 3 days, or about 6 percolators are discharged daily, making the capacity of the mill about 6000 bushels daily. This would correspond to the average output from about 40 presses, so that each of the 16 percolators is equivalent in output to about $2\frac{1}{2}$ presses. The

percolators are simply strong jacketed kettles with openings properly reënforced.

Naphtha, received in tank cars, is drained into an underground storage pit, from which it is pumped, as needed, through a coil feed water heater. The naphtha passes through the coil while exhaust steam is circulated through the shell, and the former is thus raised in temperature so as to increase its solvent power. The hot naphtha is then run into the percolator, on top of the 1000 bushels of coarse meal. The naphtha dissolves the oil contained in the meal, just as the solvent absorbs oil when testing the percentage of oil in cake, and the solution of oil in naphtha is allowed to drain off. This solution passes to the "treating tank," which is practically a surface condenser. Here it travels through tubes on the outside of which a steam pressure of from 1 to 24 pounds is maintained. This boils off the naphtha from the oil, and the latter, in the form of vapor, is carried to another condenser, where cold water is circulated in cooling pipes about which the naphtha passes and condenses. This process consequently reclaims the naphtha, which is now returned to its storage pit. The oil from the treating tank then passes to an open tank, where it is subjected to high temperature and agitated by an air blast, in order to free it from any slight odor of naphtha.

After drawing off the first run of oil and naphtha from the percolators, the latter are again sealed and live steam blown into them. This increases the temperature, and the naphtha absorbs a little more oil. The steam and naphtha vapors then pass to a condenser from the top of the percolator, while more oil, in solution in liquid naphtha, drains off from the bottom. The latter solution goes to the treating tank, etc., as before described. The vapors from the top, after condensation, are run to a large settling tank, in which the water and naphtha are separated by gravity. The former, being very pure, is used for boiler feed. The latter is run to the storage pit.

Sometimes the oil and naphtha are run to a treating tank which discharges its naphtha vapors to a vacuum pump. This results in the reclaiming of the naphtha at low temperature, a feature which results in the production of a lighter oil, better adapted for refining. The percolators are "dumped" after the last solution has been run off, and the hot meal (containing about 20 per cent of moisture) is dried on open plate driers and shipped in bags, either as discharged or after a fine grinding.

During the latter stages of the operation in the treating tank live steam is blown directly into the oil. This results in a large expenditure of steam, 1500 gallons of steam having been found to be condensed per 1200 gallons of naphtha liberated.

It cannot be disputed that the products of the "new process" are received by consumers generally with some reluctance. The meal, particularly, is objected to on many grounds. It contains very little oil, one test showing only 1.26 per cent. Stock-raisers also fear the naphtha, not realizing that the manufacturer cannot afford to sell naphtha at meal prices. The old prejudice against the oil is dying out, particularly in view of the fact that one of the best light varnish oils known is produced entirely from new-process oil. Only laboratory examination suffices to determine quantitatively any difference between properly treated new-process oil and ordinary raw oil. There are slight physical differences, more apparent, perhaps, to the consumer; but they are as often favorable to the new-process oil as to that manufactured by crushing. The percolation system has been looked upon with disfavor, and no doubt involves some danger to life and property. Many of the older plants have blown up or burned up. The use of naphtha, particularly in the form of vapor, cannot be other than hazardous. Realizing this hazard, the care and attention given to safeguarding the property results in a comparatively small number of accidental fires or threatened fires; but any serious conflagration would probably result in the total destruction of the property.

The following is a comparative estimate of the items of income and expenditure prepared by an advocate of the new process. The item "Plant" includes fixed charges on an investment of $367,500 in the case of the new-process mill. The oil and cake values are figured on the basis of No. 1 Northwestern seed containing 38 per cent of oil.

COMPARATIVE ESTIMATE ON OLD AND NEW PROCESS MILLS, 6,000 BUSHELS DAILY CAPACITY, WORKING 250 DAYS PER YEAR UNDER BEST CONDITIONS.

	Old Process.	New Process.
Plant	$ 91,035	$ 66,198
Labor	37,500	28,175
Material	2,251,000	2,274,000
Steam	14,205	20,950
Oil value	1,881,600	2,116,800
Cake value	742,560	698,880
Net income	230,420	426,357

The actual "Plant, Steam, and Labor" costs per bushel, including the cost of naphtha lost, ranged in one mill from \$.0504 to \$.0898 per bushel, over a period of five years, with an average under good conditions of about \$.06. This compares not unfavorably with the cost in an old-process mill of equal size. When we consider that the new-process meal contains about 4 per cent, or 1.5 pounds, less oil than old-process cake, making the average oil yield about 21 pounds instead of 19.5 pounds, it is apparent that the new process presents a considerable advantage in manufacturing economy. With oil worth 50 cents per gallon, an increase of 1.5 pounds in the yield is equivalent to a decrease in the working cost of \$.0133 per bushel. This may, however, be offset by discounts in the price of meal or oil.

The cost of naphtha is a leading item in the cost of the new process. A small percentage is always lost. It is desirable of course to keep this percentage down to the lowest possible point. This feature, with that of danger from naphtha escaping as vapor into the air, has led to occasional attention given the process by inventors and promoters. Carbon tetrachloride has been suggested as a substitute for naphtha. Ether and carbon bisulphide are too expensive, are explosive, and the latter would undoubtedly affect adversely the quality of the oil and meal. The percolation system has been applied to the extraction of corn oil and has been at least suggested for the reclaiming of wool grease.

The cost of steam, in the new process, has been at least double that which is obtainable with the standard method of crushing. This cost could, however, be greatly reduced. During several test runs the consumption of coal per percolator of approximately 1000 bushels ranged from 20,310 to 24,050 pounds. Some power measurements showed the impact mill used for grinding meal to consume 68 horsepower; a 24-inch attrition mill, on the same service, 27 horsepower; a car puller (starting), 43 horsepower.

The basis for any thorough comparison of working costs with those of an old-process mill depends upon a correct method of classification. In the new process no pressmen, molders, or strippers are employed; no press cloth is used. The classification of labor is as follows:

PLANT.

Mill office employees.
General mill expense.
Repair men

STEAM.

Unloading coal and loading ashes.
Engineers.
Firemen.
Engine and boiler repairs.

LABOR.

Percolator men.
Filterers.
Treating-room force.
Roll men.

SPECIAL ACCOUNTS.

Boiling and refining.
Grinding meal, including bagging.
Filling and shipping.
Coopers.

The details of equipment in one new-process mill are as follows:

Seven 72-inch horizontal boilers, with chimney 7 feet by 120 feet.
One 20 by 48 inches Corliss engine at 73 r.p.m.
Eight small engines.
One 18 by 10 by 12 inches fire pump.
Sixteen percolators 13 feet 6 inches by 14 feet.
Two 24-inch Cogswell attrition mills for grinding meal.
Two Smith-Vaile filter presses, each with 50 32-inch square plates.
One Johnson filter press, with 50 30-inch square plates.
Two Wright and Lawther filter presses, one with 50 30-inch plates, the other with 36 plates.

Besides the above an important feature in the economical operation of the mill is the "Intermediate Separator," patented by L. D. Vorce, 1901. This is a form of surface condenser, installed between the percolators and the treating tank. The steam and naphtha carried off after the second stage of percolation enter the tubes at a temperature of about 225 degrees. Into the shell of the separator is brought the solution of oil in naphtha which has left the bottom of the percolator at a temperature of about 100 degrees. The solution is consequently boiled by the waste heat in the tubes, and some of the naphtha is driven off, while the vapor in the tubes is partially condensed. As both operations are performed by heat which would otherwise be wasted, steam is saved in the treating tanks and in the operation of finally condensing the steam and naphtha vapors. The oil entering the shell of the separator contains about 75 per cent of naphtha, the steam entering the tubes from 50 to 80 per cent. With this equipment about 720,000 pounds of naphtha may be reclaimed per day by

the treating tanks installed, and the consumption of steam is decreased to one gallon per 4¼ gallons of naphtha reclaimed. The separator contains 1300 square feet of heating surface.

The percolators are of the square-bottom type. Partially hoppered bottoms would reduce the cost of labor for dumping out the spent meal.

The analysis of new-process meal is stated as follows:

New-Process Meal.

	Per Cent.
Oil	1 50
Water	9 18
Ash	4 90
Fiber	9 04
Albuminoids	41 60
Carbohydrates	33 78
Total	100 00

The meal is advertised to contain from 1.5 to 2.5 per cent of oil, and not less than 40 per cent of albuminous matter.

The cost of good mill buildings for a new-process plant is about as follows, per 1000 bushels of daily capacity: Percolator house, $35,000; meal house, $10,000; treating house, $7500; boiler house, $6000; naphtha storage, $3000; cooperage and filling house, $2000.

A large part of the oil is necessarily subjected to special treatments, in order to make it find favor in the market, comparatively little being sold as raw oil. The leading new-process special oils are the refined, the varnish, and the P.M.P. These are discussed elsewhere.

For many years crushers have endeavored to find a substitute for the hydraulic press, necessarily intermittent in its action. The first practical mechanical press for the continuous extraction of linseed oil was built about five years ago by the V. D. Anderson Company of Cleveland. Several of these presses are now in successful operation. There is a plant of nineteen of them at Cleveland, another large plant at Montreal, one of seven presses in Chicago, another of twelve presses now being installed in the same city, with a large number of single-press plants at various points. Several of the Anderson machines are used in the South for expressing cotton-seed oil. A twelve-press linseed plant has just been completed at Milwaukee. In all of the plants mentioned the continuous tempering apparatus, to be described later,

is employed. A perfectly uniform temperature of meal up to 190° F. may be maintained, with an unusually uniform yield.

The writer tested one of the first of the Anderson machines in

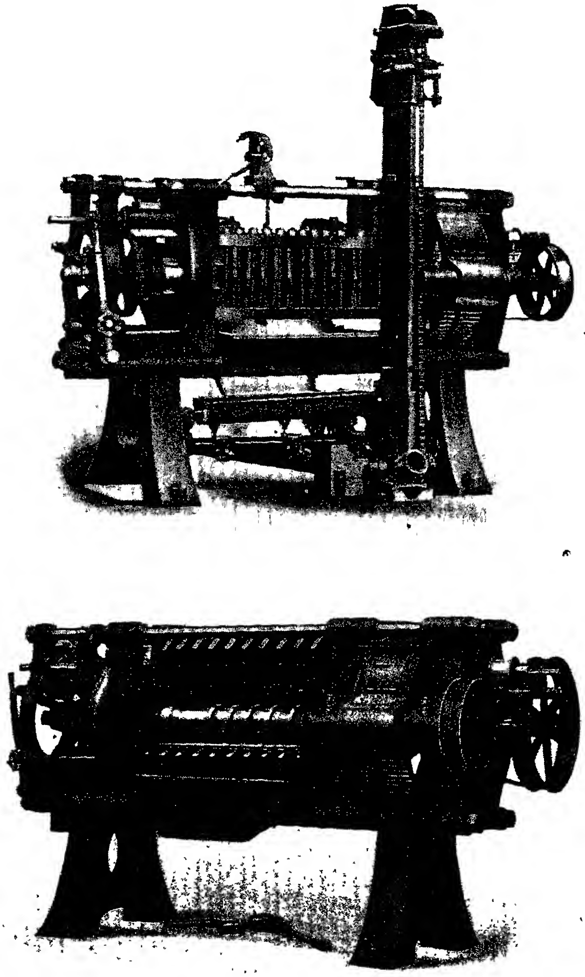


FIG. 49. — THE ANDERSON EXPELLER.

1903–04 on whole (unground) and uncooked seed. Even at that time yields of from 15.84 to 16.40 pounds of oil had been obtained under these conditions. The writer's tests gave less favorable results; but the recent improvements in the machines with regard to details of

construction have so increased their rigidity and strength as to give greater capacity and more efficient extraction. A capacity of 8 bushels per hour is now guaranteed on tempered meal, with a cake test not exceeding 8 per cent, and sometimes falling nearly as low as 5 per cent.

The Anderson machine, an illustration of which is given in Fig. 49, subjects the whole or ground seed to the end thrust of a powerful worm. Its operation is continuous and automatic. One man can easily care for ten machines, and the labor cost is consequently largely eliminated. Fig. 50 illustrates a press room containing a row of ten of these machines. Fig. 51 gives the principal dimensions of one

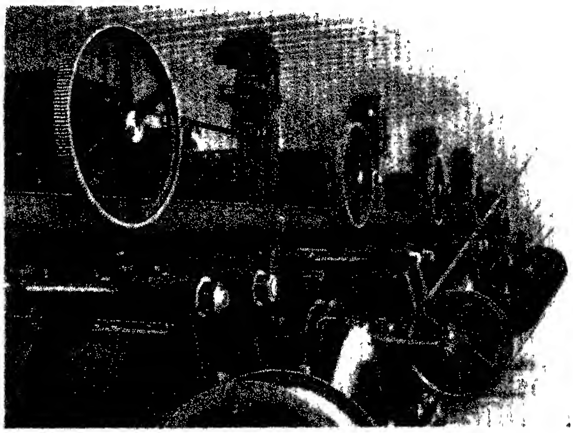


FIG. 50. — EXPELLER PRESS ROOM.

"expeller" of standard size. Fig. 52 shows the expeller, with auxiliary machinery, consisting of a small stand of rolls and a continuous heater, forming a complete installation, for a single machine. Referring to Fig. 51, the pressing of the seed is performed in a perforated hardened steel cylinder, in which revolves a shaft, carrying a series of hardened steel screws, so arranged as to produce a gradually increasing pressure. The degree of pressure is regulated by the cone at the end of the cylinder. The oil is expelled through the perforations of the cylinder, and drops in the oil strainer, and from thence into the pan A. The foots accumulating in the strainer are fed automatically into the elevator B, which returns them into the feed hopper. The pressed cake is discharged at the opposite end of the cylinder at the point C.

Fig. 52 shows the front elevation of a complete one-expeller oil plant. The seed is spouted into the roller mill *D* and from there elevated into the tempering apparatus, and after passing its entire length, drops into the hopper of the expeller. This makes an entirely automatic

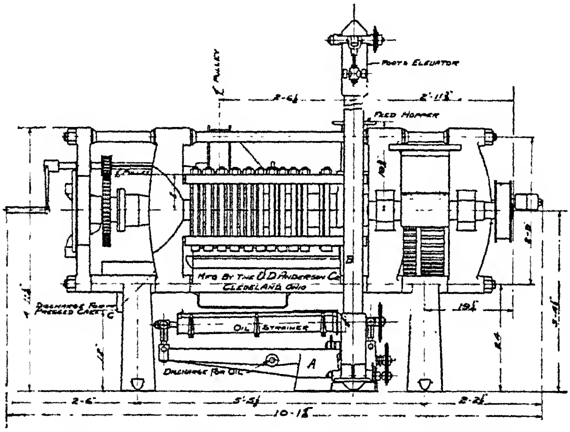


FIG. 51. — DIMENSIONS OF STANDARD EXPELLER.

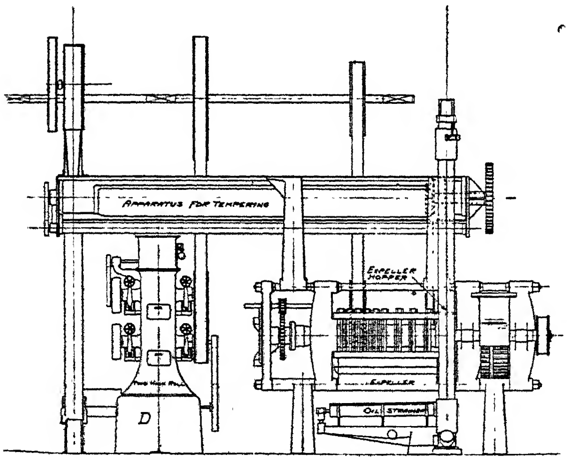


FIG. 52. — EXPELLER OIL PLANT.

and continuous operation from the moment the seed enters the mill until the oil is pumped into the filter press and thence into the barrel or storage tank and the cake sacked or fed into the grinding mill.

When a plant of several expellers is wanted, it is desirable to use the type known as the "end-drive" expeller, shown in Fig. 53; this

expeller lends itself more readily to being arranged in rows, as several machines can be driven from a single overhead line shaft.

All seeds can be pressed cold, and without grinding, but the best results are obtained by flattening and breaking up the seeds in a mill, composed of two rollers, and then slightly warming the meal in a tempering apparatus, before introducing it into the expeller. In this way is obtained the maximum yield of oil.

The oil as it comes direct from the machine, being cold, may be at once pumped through the filter press, and at the end of the day's run

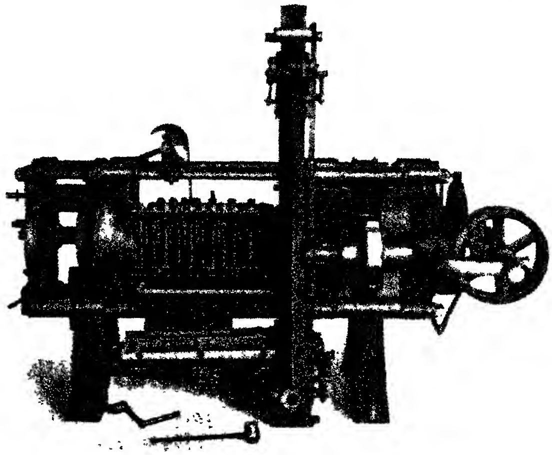


FIG. 58. — END DRIVE EXPELLER.

or at any time during the run the operator can tell exactly the yield of filtered oil that is being obtained from the material under treatment. No settling tanks are required when using this process.

The meal is ordinarily warmed only to 140° F in the tempering apparatus, which is not a sufficiently high temperature to soften the albumen, and this consequently remains in the cake. The oil which is produced by this low-temperature treatment, like cold-pressed oil, will not "break," i.e., it remains perfectly clear at a temperature of 500° F., which makes it valuable for paint and varnish purposes. As to the cake, the larger percentage of albumen referred to above makes it more valuable, while the albumen is more easily digested in its raw state than when cooked. More thoroughly cooked seed may of course be pressed, thus obtaining a yield more nearly equal to that

secured by the hydraulic process. Less horsepower is required for pressing cooked seed, and a larger quantity of seed can be pressed per hour.

Besides the saving in labor, the expeller uses no press cloths. The continuous tempering attachment makes the tempering and the yield of oil comparatively uniform. The expeller has a capacity of about 8 bushels per hour, somewhat greater than that of the average press, on crushed and cooked seed. It consumes about 10 horsepower, about the same as the power consumption of the hydraulic press mill. Like the process of percolation, the expeller process possesses both advantages and disadvantages over the old process, the advantages, in the case of the expeller, rather outweighing the disadvantages. Its prime feature is that it permits of linseed crushing on a small scale, with a limited capital investment, by paint and varnish manufacturers, at a relatively low manufacturing cost. It requires little space, no foundation, will produce a full yield even if not continuously operated, and produces an oil suitable for varnish making without subsequent treatment. The cost of producing linseed oil is, however, so largely affected by other considerations than the expense of running the mill, that the widespread manufacture of their own oil by paint grinders and varnish makers need not be looked for. The best reported yields with the expeller process do not equal those obtainable under the most favorable conditions in the hydraulic mill.[1]

Reference has been made to the improvements in old-process equipment proposed by A. B. Lawther, page 51. In this process the flax-

[1] A profitable mode of operation of the Anderson machine is in the production of cold-pressed oil and ground flaxseed. On whole, uncooked seed, the minimum yield is never less than 12 pounds of oil. After settling, this oil is of a brilliant color, and does not "break." The residual cake can be run through the old-process mill in the regular way. In some cases it is mixed with equal quantities of ground flaxseed. The latter course is more profitable, if legitimate. The cost of seed being taken at \$1.12, and the working cost at \$0.26, the total cost is \$1.38. For a production of 12 pounds of oil and 44 pounds of cake, the oil at 50 cents per gallon returns 80 cents per bushel, leaving the cost of cake \$0.58 for 44 pounds. If marketed as ground seed, the cost of barreling, grinding, and mixing amounting to about \$0.23 per 44 pounds, the total cost of the ground "seed" thus produced is about \$0.018 per pound, a low figure. The cold-pressed oil bleaches nearly water white at a temperature of 600° F. The "ground flaxseed" is of fine quality such as cannot be produced from whole seed alone at prevailing prices. The daily capacity of the machine operated in this way may be conservatively set at 2 barrels of cold-pressed oil and 20 barrels of ground flaxseed.

The United States Pharmacopœia provides that "ground flaxseed" shall be recently prepared and free from unpleasant or rancid odor. "It is a grayish yellow powder containing brownish fragments and when exhausted by carbon disulphide should yield not less than 30 per cent of a fixed oil, all of which is saponifiable. If 0.1 gramme of ground

seed first goes through the crushing rolls and is then conveyed to the heaters, where it is thoroughly steamed and agitated, and by an elevating device is carried over into a cake-forming meal tub, where by the pressure of a plunger through an opening exactly the size of the cake the meal is pressed downward on a table. The underlying cloth is drawn over the cake and folded by a mechanical device, no hand labor being required up to this point except for the laying of the cloth on the pressing table. The table moves automatically to the press, where by means of nippers the cake is pulled from the table into the press and is ready for compression. As fast as these various operations are performed the machinery is reversed by its own mechanism and immediately begins a new cycle. The process is continuous, and is controlled by the amount of seed that is fed into the rolls for crushing at the beginning. It does not appear to have yet been practically applied.

Oil crushing in Europe is generally by means of hydraulic presses, the machinery being modified from the types common in this country mainly on account of the increased percentage of oil carried in the cake. European mills are cake producers rather than oil producers. The presses are without mats, having brands in the plates, which are ribbed crosswise. * The low hydraulic pressure is about 800 pounds, rather higher than is customary on this side of the Atlantic. Rather light cakes are made. The men handle about the same number of cakes per hour as in this country.

Brannt's *Animal and Vegetable Fats and Oils* contains a list of United States patents from 1790 to 1887 describing methods and processes for the expression, extraction, and treatment of oils. This list should be suggestive to the inventor.

flaxseed be heated with 20 c.c. of water to boiling, then cooled and diluted with cold water to 100 c.c., the addition of .5 c.c. of iodine should not produce more than a pale blue color (limit of starch)."

According to the United States Dispensatory, "damaged flour or other starchy material is often introduced in grinding, and is at once detected by the microscope or iodine test. The commonest sophistication is the substitution in whole or in part of the linseed meal used as cattle food, made by grinding up linseed cakes left after the expression of the oil. This is detected by the less oily appearance of the mass and by the reduced percentage yield of oil (less than 25). To restore the appearance mineral oil is sometimes added, but the saponification properties have thus been lost or impaired. In commerce the percentage of impurities is roughly determined by shaking in a muslin bag. The impurities settle in the conical point. Foreign seeds and earthy impurities should not exceed 2 or 3 per cent and are often less than 1 per cent. Occasionally they amount to 25 per cent or more. Such seeds consist chiefly of mustard and rape and their relatives. Sand and small stones may be present, due to imperfect cleansing."

CHAPTER XIV.

THE SEED CROP.

The flax plant.—Flax fiber.—Cultivation of flax.—"Flax-sick" soil.—Use of formaldehyde.—Professor Bolley's investigation.—Flax does not require an especially fertile soil.—Growing flax.—The flax seed.—Analysis of seed.—Yield of seed per acre.—Cultivation of flaxseed in the United States.—Westward movement of the crop.—Statistics of the linseed industry in this country.—The world's crop.—Russia.—British India.—The Argentine.—Consumption of flaxseed in various European countries.—Derivation of their supply.—Details of the flax crop of the world.—Waste of the fiber.—Method of preparation of fiber.—Possibilities of utilization of seed and fiber.—Economic consequences.

THE flax plant belongs to the natural order of *linacæ*, subdivision *linum usitatissimum*.[1] The twig terminates in a globose capsule, about one-fourth inch in length, containing five cocci, in each of which are two seeds. These are the linseed of commerce. The plant is an annual, growing from 20 to 40 inches high. The seeds vary in length from one-seventh to one-fifth inch. There are numerous varieties of flax, the parent being unknown. It is grown in the central, western, and northern parts of the United States, Canada, the Argentine Republic, Uruguay, India, Russia, and, on a small scale, in most European countries.

The plant was formerly used for fiber only, and classification was made with regard to considerations of fiber value. In Europe the plant is cultivated with a view to the utilization of both seed and fiber, the

[1] It has a thread-like tap root, sparingly supplied with tender branches. The leaves are simple, narrow, entire, and nearly sessile. It has perfect, symmetrical, rather conspicuous blue flowers, all parts being in fives. The carpels, however, are divided by a false partition, hence the capsule or seed boll is usually ten-celled and ten-seeded. The seeds are botanically described as "lenticular, compressed, with a smooth polished surface, varying in color from yellow to dark brown, light brown being the standard color." The average germination of flax seeds is about 85 per cent. The Canada Station found the decrease in viability during five years to be as follows: 81, 82, 75, 49, and 26 per cent. The endosperm which surrounds the embryo is comparatively thin, and in mature seeds contains no starch. —From *The Forage and Fiber Crops in America*, by Prof. Thomas F. Hunt. (Orange Judd Company.)

oil from the seed being of comparatively low value. The harvesting is done before the seeds have reached the stage where the percentage of oil is at its maximum. In this country, in the Argentine, and in India flax is raised for the seed only, and the percentage of oil in the seed is higher.

For the cultivation of flax, land of firm texture on a moist subsoil is regarded as best. Typical English soil is good, but the owners oppose the growing of flax on account of its tendency to impoverish the soil.[1] This is partially avoided by alternating the crop with oats or potatoes.[2] The cultivation of flax is very simple. Ordinarily for the best fiber it should be pulled as soon as the flowers fall. By improved processes of steeping, the value of the fiber is not damaged by allowing the seeds to become nearly mature. The pulling is, however, done in any case before the seeds are dead ripe, or as soon as they turn slightly brown. The preparation of flax fiber for the market before shipping requires much field labor — another reason why no progress in this direction has been made in our Northwest. The fiber is made from the stalks, the membrane or rind being loosened by drying in the sun and beating. The inner portion or core of the stalk makes the best fiber, the outside forming the tow.[3] The farmers' rule when raising flax for fiber is to pull before the capsules are quite ripe and when changing from a green to a pale brown color. At this time about two-thirds of the stalks should be yellow. A very small amount only of good flax fiber is produced in the United States or Canada.

Professor H. L. Bolley of the North Dakota[4] Agricultural Experiment Station has investigated the question of impoverishment of soil due to the growing of flax. It has been known for many years that flax will not succeed itself on the same soil and remain strong; in each new

[1] Flax fiber is produced principally in the cool, moist, low-lying regions of Northern Europe. The plant may be grown for seed in any climate or soil suitable for wheat. Sandy loams are better than heavy clay loams.

[2] According to investigations of the United States Department of Agriculture, flax removes less nitrogen from the soil than corn; less phosphoric acid than potatoes, peas, corn, barley, or wheat; and less potash than any other grain. — See Farmers' Bulletin, No. 69, page 6.

[3] The long straight lint is from 12 to 36 inches in length. The short tangled fiber which separates from the long lint in dressing is classed as tow, and is used for upholstering and for making twine, coarse bagging and toweling, and paper.

[4] This state, a pioneer in pure-paint legislation, is now interested in the attempted development of a species of flax which it is hoped may prove immune to the attacks of the *fusarium lini*. The work of Professor Ladd on this problem is well known.

locality in which flax has been introduced it has proven a short-lived crop. Iowa was first the principal Northwestern flax-raising state, then Minnesota, and now North Dakota. Wherever flax has long been raised it has been abandoned as an unprofitable crop, the farmers explaining that the soil is "flax-sick." Many farmers think that flax exhausts the soil, but by a proper rotation of crops flax may again be profitably raised on flax-sick soil.

The number of crops that can be successfully grown in the Northwest is limited, and it would be a serious matter for the farmers if flax had to be stricken from the list. It is found, however, that six years of continuous flax cropping on a piece of the richest Red River Valley land reduced it to such a diseased condition that not one plant of flax could exist upon it longer than three weeks from the time of sowing. In the face of this Professor Bolley has demonstrated that flax is not an exhausting crop and that an average yield of flax will not remove from the soil as much fertility as a 30-bushel crop of wheat or 150 bushels of potatoes. Flax-wilt and flax-sick soil are caused by a fungus, *fusarium lini.* This fungus is generally introduced with the seed, and once in a field maintains itself, increasing with each succeeding crop and living on the plant. The only way to get it out of the soil is to change to other crops on which the fungus cannot live. It has been shown that it is possible to kill the fungi by treating the seed with a wash of a solution of formaldehyde in water. Probably no sample of flaxseed is entirely free from this fungus. The simple treatment with formaldehyde gas kills it before it ever gets into the soil.

Professor Bolley's work has been of such immense importance to growers of seed and manufacturers of oil that we quote at some length from the *résumé* incorporated in Farmers' Bulletin, No. 274, of the United States Department of Agriculture, on Flax Culture:

The one thing that the flax crop cannot stand is a friable, loose-textured soil. The best flax soils are found to be those with an admixture of very fine sea sand or silt resting upon a heavy compact subsoil.

Fall plowing is apt to give the best results in all those types of soil which tend to become more compact by working. In very rich, loamy soils, which are liable to become loose and friable by persistent working — such, for example, as the lands of the Red River Valley — the top-working should be confined to the destruction of weeds and should be stopped at the slightest sign that overwork is tending to looseness, liability to blow, etc.

A compact soil underlying a shallow seed bed of not to exceed 1 inch in depth always gives the best results. The deep plowing and working should precede the seeding time

just as long as possible. The seed is sown as soon in the spring as the work can be accomplished and not have the young plants injured by frost.

Northward and northwestward in America, including the Dakotas and Minnesota, the crop may be sown with hope of success even until the 10th or 20th of June. In North Dakota, if the late crop is not caught by early frosts, the yield is apt to be even greater than that from the early sown crop, which at times may be compelled to ripen too rapidly

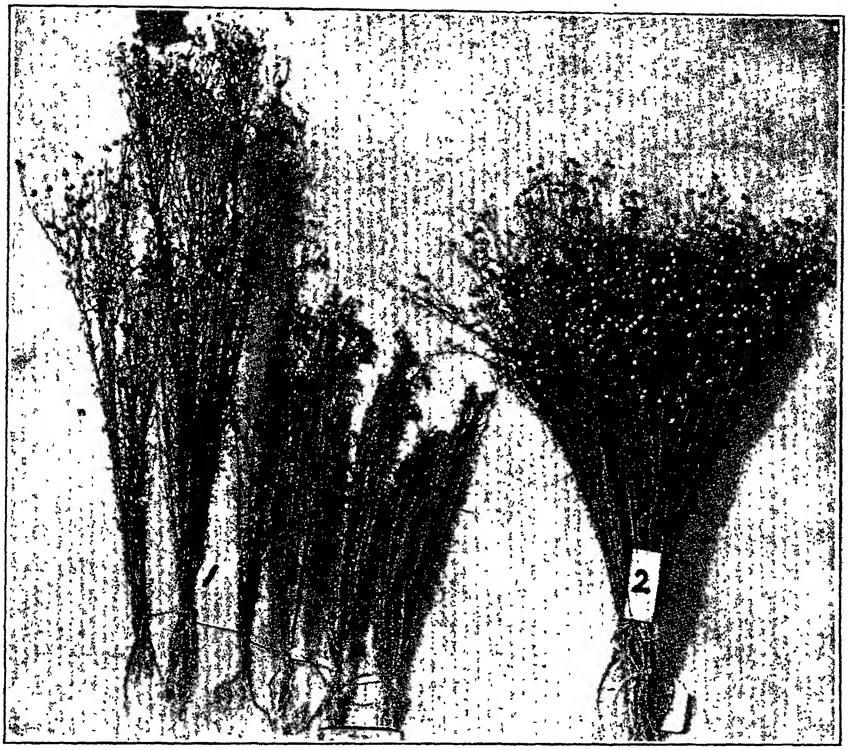


FIG. 54.

Bundles of flax all grown from the same variety of seed, sown on the same day upon the same plat, showing the evil effects of irregular depth of planting. (1) Depths of planting, respectively ½ inch, 1 inch, 1½ inches, 2 inches, 2½ inches, 3 inches; (2) crop planted evenly at one inch depth. (Farmers' Bulletin No. 274, United States Department of Agriculture.)

by the action of heat in August. The early crop also seems to be more often injured by rust. However, the date of seeding in North Dakota cannot be much earlier than May 20 or later than June 20.

The methods of seeding for flax are as various as the people who grow the crop. The larger areas of the Netherlands and Belgium are seeded with ordinary grain drills, and such machinery is also used upon the largest estates in Russia where the crop is grown for oil production.

The seed should be embedded at an even depth, not too deeply, and should be evenly

distributed. The brush harrow, as commonly made by American farmers, gives good results when properly handled.

Trials at the North Dakota Agricultural Experiment Station have demonstrated that a matter of difference in depth of planting may cause differences of several weeks in ripening the seed crop.[1]

With the flax grower, crop rotation is of great practical importance. He must either rotate or cease to grow the crop. A very common rotation in the Netherlands is as follows: (1) Manure or rape; (2) wheat; (3) rye; (4) legumes (horse beans); (5) flax; (6) potatoes; (7) potatoes; and (8) fallow — rest, and crop of weeds turned under as a green manure late in the season. If the soil is very fertile, the potatoes follow the legumes, preceding the flax.

In Russia the peasants, according to the compulsory customs of the particular commune, practice either three or six year rotations. In the better flax-producing villages the rule is usually for a six-year rotation, as follows: (1 and 2) Wheat; (3) oats; (4) rye; (5) pasture; (6) flax.

In the northern regions of Russia, the peasants allow the land to run wild as a village pasture and to grow up to scrub timber for ten or fifteen years. The scrub is then burned off and the breaking is cropped to flax. The land cleared in this way seems to have all the advantages of virgin soil.

A leguminous crop is of much benefit in preparing the soil for flax culture. If, however, the soil naturally possesses much available nitrogen, the flax is sown as long after the leguminous crop as possible and is usually preceded by grass or hay crops.

Very little need be said of weeds. There is probably no crop in which their presence is more pernicious than in flax culture. In the seed crop they occasion by their extra foliage great difficulty in properly drying and curing the seed bolls for thrashing. The greatest difficulty is also experienced in attempting to grade weed seed from flaxseed. Among the destructive weeds represented in seed are flax dodder (*Cuscuta epilinum*), cornflower (*Centaurea cyanus*), many types of mustard, including false flax (*Camelina sativa*) and various species of Roripia.

Great care is necessary in the harvesting process in order to hold the quality of the seed. The seed should be allowed to mature, be harvested dry, and be kept in a dry condition.

A soil trouble is recognized in practically all flax-producing countries. It manifests itself in a gradual dying of the crop from the time the seed begins to germinate until the crop is quite mature, in the later stages giving the appearance which may well be designated as wilt. As the plants rapidly dry up after dying, they assume a blighted appearance as if struck by fire.

The soil is then said to be "flax-sick" or "exhausted" for flax culture. (See Fig. 55.) It has been demonstrated at the North Dakota Agricultural Experiment Station that the trouble is not primarily with the soil, that the soil is not chemically exhausted, but that the trouble is due rather to the presence in the soil of micro-organisms. The chief one of these organisms has been named *Fusarium lini*. The writer has since found that there are several species of Fusarium which act in the same manner, that a species of Colletotrichum is destructive at times and that various species of Alternaria are able to do much damage to the flax crop under certain weather conditions.[2]

The fungous troubles are usually introduced into a new soil by the seed which is sown,

[1] See Fig. 54.

[2] "Flax rust (*Melannospora lini*, *D. C.*, *Tul.*), recognized by the yellow or orange spots on the older parts of the nearly mature stems, is not considered seriously injurious to plants grown for seed." — *The Forage and Fiber Crops in America*, by Prof. Thomas F. Hunt.

and bits of old straw, chaff, and other matter which contain the living organisms are also thus distributed in the soil. By proper treatment of the seed by the formaldehyde method it is possible to prevent the occurrence of the diseases, provided the land is not already infected. Various individuals, varieties, and strains of flax may exhibit a high degree of immunity or resistance to the attacks of these wilt diseases. The careful pulling of all of the straw and its removal to distant retting grounds, it is believed, also tend to dispose of one of the great sources of disease accumulation in the soil.

There are several well-marked varieties of cultivated field flax. (See Figs. 56, 57.) Among these there are at least two which should be classed as species, namely, *Linum usitatissimum* L., including all of the small-seeded varieties, and *Linum humile* Mill., including the large-seeded varieties.

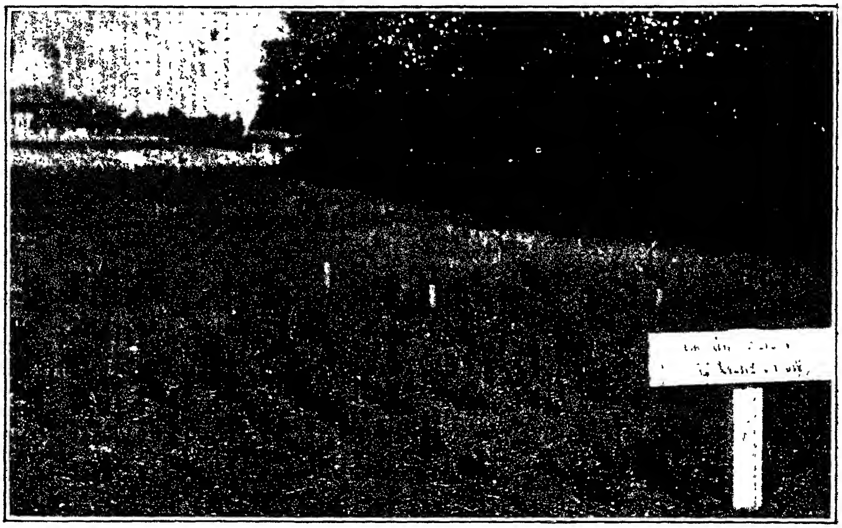


FIG. 55.

"Flax-sick" ground, showing the method of testing various samples of Russian flaxseed to determine their resistance to wilt diseases. Second year's trial. The dying away of the crop is apparent. (Farmers' Bulletin No. 274, U. S. Department of Agriculture.)

There seem to be many intermediate grades or strains. Studies conducted upon the varieties of these two species of cultivated flax tend to indicate that they are usually close-fertilized. Individual flowers, for example, produce seed freely whether in association with other flowers or not. The structure of the flowers, while possibly allowing cross-fertilization, is such as to indicate that they do not usually cross-fertilize to any great extent.

There are regions where, even now, without special knowledge of the existence of disease, the farmers have succeeded, through careful culture and rotation, in saving the crop and keeping it a permanent element of the local agriculture. In Europe the most noted locality in this respect is that immediately surrounding Courtrai, in Belgium. There is only one bar to the possibility of the crop becoming a permanent one, viz., the presence of persistent soil-infecting diseases. The most important features in preventing disease

consist in each farmer raising, cleaning, and grading his own seed flax and in seed disinfection.

Treatment of Seed with Formaldehyde. Good, bright, plump, yellow flaxseed is selected and cleaned in a fanning mill until only heavy-weight seeds remain, all bits of straw, chaff, dust, and scaly seeds being blown out. The formaldehyde solution is made to the strength of 16 ounces of standard formaldehyde to 40 gallons of water. The cleaned flaxseed is laid upon canvas or a tight floor in quantities of 5 to 10 bushels, and the seed

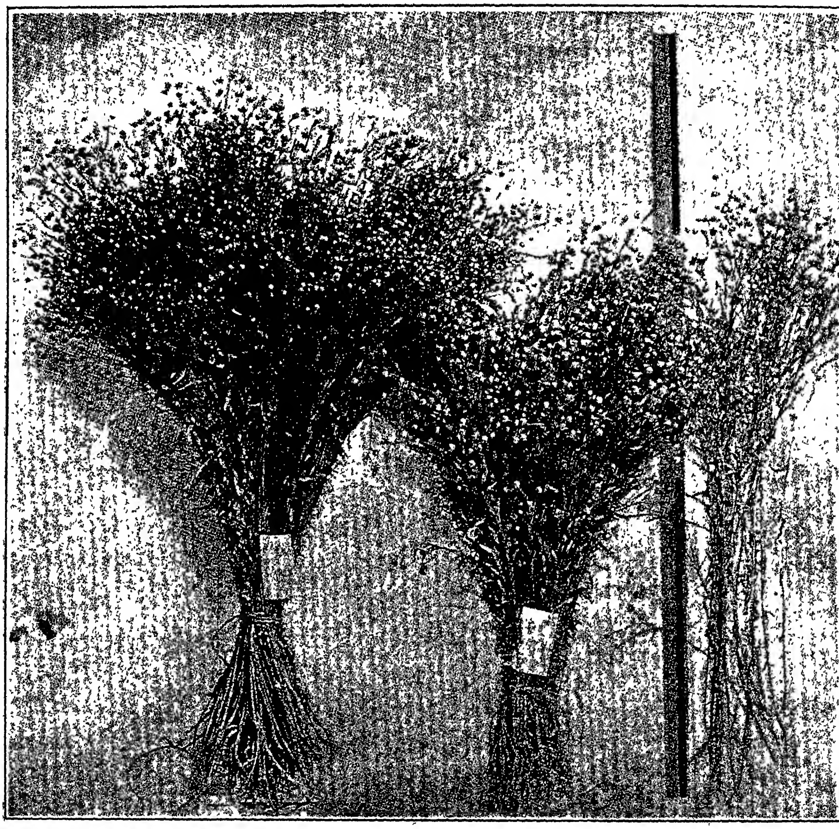


FIG. 56.

Types of North Dakota grown Russian seed flax of three distinct varieties. (Farmers' Bulletin No. 274, United States Department of Agriculture.)

is gradually moistened by the use of a fine spray thrown from a small force pump while it is being rapidly shoveled or raked over. In this manner the flaxseed quickly moistens over its external surface and can be thoroughly dampened without causing it to mat together, the process taking one-half gallon of solution per bushel of dried seed. It is of advantage to cover the pile of seed with canvas or a blanket for a few hours after treatment to keep the exterior of the pile from drying too rapidly. Grain thus treated, when once or twice shoveled over, will readily run through an ordinary drill in two hours after treatment.

FIG. 57.

Four types of flax fiber, and a bundle of North Dakota grown Russian fiber flax from seed sown at the rate of one-half bushel per acre. The latter shows the coarsest form, 47 inches in length. (1) Best quality Belgian fiber; (2) best quality north Russian prepared fiber; (3) hand-broken and scutched fiber prepared from North Dakota grown dew-retted straw; (5) hand-broken and partly scutched fiber from coarse North Dakota grown straw similar to that shown alongside. The fiber in bundle No. 3, while somewhat longer and more tangled, appears in no way inferior to the Russian product, No. 2. (Farmers' Bulletin No. 274, United States Department of Agriculture.)

The customary assumption that an especially fertile soil is required for flax has been investigated by the Minnesota Agricultural Experiment Station. Of the four elements in a perfect plant food, flax requires principally nitrogen. This of course is most abundant on new soils. The rotation of clover with flax should be practiced where flax is to be a permanent crop. The Oregon Agricultural Experiment Station recommends a six-year rotation of wheat, oats and barley, clover and grasses (two years), corn and potatoes, and flax. The cultivated crops result in the destruction of weeds. If barnyard manure is used to supply nitrogen, it must be well rotted.

Flax can be grown, either for fiber or seed, in latitudes between 10 and 65 degrees north, and probably within similar latitudes south. It grows best in the colder portions of the temperate region. The seed crop may be most successfully grown under the same climatic conditions as spring wheat. In southern France, flax is sometimes cultivated as a winter annual, but it is more usually sown as a spring crop. A sturdy woody type of stem growth should be sought, with a heavy production of foliage. Too much moisture during the growth season results in weak and imperfect stems and poor boll and seed formation. A severe drought, on the other hand, at or near the time of flowering, will prevent the proper flow of sap and cut off the food material from the seed. A soil must be selected which can be depended upon to supply moisture during drought. Seed germination should be rapid, and the soil should be so fine as to permit the seedlings to come up immediately.

The seeds of the flax plant are flat, oval, lustrous dark brown in color, with a beak at one end, and each seed consists of mucilaginous coats containing a large, straight oily embryo with oil-saturated cotyledons and a short radicle. The mucilaginous matter in these coatings is viscid in hot water. The largest seeds are produced by plants grown in the tropics. The greatest yield of oil, however, is obtained from plants grown in colder climates. It is estimated that six Sicilian, thirteen Black Sea, or seventeen Archangel seeds weigh one grain. The ancient Greeks and Romans used the seed for food, in both the raw and the roasted conditions. The oil is now occasionally used for food in Russia, Poland, and Hungary. Careless harvesting and cleaning of flaxseed occasions adulterations of flax-dodder, oats, poppy bolls, weeds and grasses (such as water grass and pigweed), wild rape,

dust, finely broken hulls, mustard, straw, chaff, corn, sesame, and in the case of Calcutta seed, *terra alba* (fine white clay.) The generic names for all these adulterations are "buffum," "dockage," "impurity," and "screenings," and in flax as delivered after threshing and running through the cleaning machinery of a well-equipped elevator they seldom exceed 2 per cent. Some of them form and produce oil, sesame, for instance, having a greater percentage of oil than linseed; others contain very little oil, the average percentage in average samples of dockage from Northwest American seed being 10 per cent. No attempt is made by linseed crushers to greatly decrease the amount of impurities, as ordinary conditions of flaxseed purchase make these a considerable advantage to the buyer, and they add to the weight of cake. Southwestern seed of the United States is heavier than Northwestern, contains from 4 to 6 per cent less oil, and is more free from pigweed and water grass. The average seed contains upward of 3 per cent of ash and about 8 per cent of moisture.

Our American Northwestern seed contains upward of 38 per cent of oil. It is planted at the rate of from 2 to 3 pecks of seed per acre. The straw is almost invariably wasted.

The new crop of linseed produced in the United States comes on the market in September, Argentine seed usually reaches New York in April, or shortly after, and Calcutta seed in May. Northwestern land when freshly broken to flax will grow from 10 to 15 bushels of seed to the acre under favorable conditions. This amount of seed is from stalks which will produce two tons of straw.

It has been found that seed from two to six months old gives a less viscous and turbid oil than fresh seed. Mature seed gives a lighter oil than young seed.

The cultivation of flax was originally practiced for the production of fiber from the straw. A limited domestic demand for the seed soon resulted in its production, and by 1791 seed began to be exported.[1] With the introduction of the cotton gin, in 1792, the production of flax fiber greatly decreased. By 1810, flax was being grown for its seed to such an extent that there were 283 linseed-oil mills in the

[1] Even earlier exportations are recorded. Benjamin Franklin, in testifying before the House of Commons, in 1766, in connection with the proceedings leading to the repeal of the Stamp Act, stated that 70,000 bushels of flaxseed had been shipped from Philadelphia to Ireland in 1752. (Franklin's *Essays and Correspondence.*)

14 states.[1] These were, of course, very small mills, the total annual output being 770,583 gallons, or say not much over 400,000 bushels of seed, a quantity which one of the present mills might consume in a single month. The importation of flaxseed began in 1839. From 1850 the larger part of the seed from which oil was expressed in the United States was brought in from India. From 1850 to 1860 half the entire domestic flaxseed crop was grown in Ohio and Kentucky. Western mills utilized this seed, the Eastern mills importing their supply. Western mills thus obtained seed cheaply, and were led to produce meal in order to avoid freight costs on cake. Eastern mills secured a seed containing a much higher percentage of oil. From 1850 to 1875, imports of flaxseed increased eightfold; meanwhile the domestic production also increased, but not to such an extent as to supply the demand from the Eastern mills until 1892; since which last date, with the exception of one or two short-crop periods, imports of flaxseed have been insignificant.

In 1850 Ohio was the leading state producing flaxseed. By 1869 Indiana and Illinois were close competitors. A steady migration to the West and Northwest has followed, until at present the principal producing states are in two groups, one, the Northwestern,[2] comprising North Dakota, Minnesota, South Dakota, Iowa and Wisconsin, and the other, or Southwestern, including Kansas, Missouri, Nebraska, Oklahoma, and the Indian Territory. In 1902, 53 per cent of the entire flaxseed crop of the United States was grown in North Dakota; in 1906, 56 per cent. The five Northwestern states produced in the former year 92 per cent of the total crop. The fact that the Northwestern seed is richer in oil than the Southwestern is stated to be due to the introduction of a foreign variety of seed in South Dakota soon after that state had become an extensive producer. The Southwestern production is consequently declining, both absolutely and relatively.[3] Whether further migration will result in the disappearance of flaxseed production from our Northwestern states, carrying it into Idaho, Montana, Oregon and

[1] "Flaxseed Production, Commerce and Manufacture in the United States," by Charles M. Daugherty, from the yearbook of the United States Department of Agriculture for 1902.

[2] The Northwestern seed varies somewhat in percentage of oil. That grown in Minnesota is slightly, and that in Iowa seriously, inferior to the seed production in the other three states.

[3] It is now about 1,000,000 bushels per year.

Washington, and the Canadian Northwest, is an interesting question, as is also that of the consequent effect on the attitude of American crushers toward the tariff.[1]

FLAXSEED STATISTICS OF THE UNITED STATES.

Year.	Domestic Crop.	Imports of Oil[2] Considered as Seed.	Imports of Seed.[7]	Exports of Seed.	Total Supply.
	Bushels.	Bushels.	Bushels.	Bushels.	Bushels.
1850	562,312	748,927	664,868	....	1,976,107
1860	566,867	267,528	2,748,440	....	3,582,835
1870	1,730,444	47,890	2,791,336	....	4,569,670
1880	7,170,951	36,216	1,464,195	....	8,671,372
1881	9,000,000	....	908,191	....	9,907,834
1882	7,500,000	....	635,079	....	8,135,079
1883	7,500,000	....	637,729	....	8,137,729
1884	6,500,000	....	2,849,226	....	9,349,221
1885	8,500,000	....	2,548,864	....	11,048,864
1886	13,000,000	....	1,034,576	....	14,003,662
1887	10,000,000	....	415,179	....	10,415,135
1888	10,500,000	....	1,583,964	37,265	12,046,699
1889*	9,000,000	....	3,259,460	....	12,259,435
1890	10,250,000	....	2,391,175	14,678	12,626,495
1891	8,500,000	....	1,515,546	144,848	9,870,697
1892	19,000,000	....	285,140	3,613,187	15,671,953
1893	11,104,440	....	112,015	1,837,370	9,379,085
1894	10,000,000	....	592,820	2,047,836	8,544,984
1895	7,500,000	....	4,166,222	1,224	11,664,998
1896	15,000,000	....	754,507	80,453	15,583,576
1897	17,402,000	....	105,222	4,713,747	12,773,583
1898	12,500,000	....	136,098	257,228	12,376,698
1899	16,400,000	....	81,953	2,830,991	13,650,962
1900	19,979,492	....	67,379	2,743,266	17,303,605
1901	17,592,000	....	1,631,726	2,755,683	16,446,931
1902	25,319,000	....	477,157	3,874,033	21,857,376
1903	29,284,880	....	129,089	4,128,130	25,265,628
1904	27,300,510[3]	....	....	26,700	27,273,810
1905	28,478,000[4]	....	....	1,409,000	27,069,000
1906	25,576,000[5 6]	....	....	9,805,000	15,771,000
1907	25,862,000	....	....	4,000,000	21,862,000
1908	25,805,000	....	....	....	....

(Compiled from various sources.)

[1] The 1902 Year Book of the United States Department of Agriculture gives (p. 428) the producton of flaxseed in each state by decades from 1849.

[2] Small amounts of linseed oil are still regularly imported.

[3] Average yield, 10.3 bushels per acre.

[4] 25,000,000 bushels grown in North Dakota, South Dakota, and Minnesota.

[5] 23,200,000 bushels grown in North Dakota, South Dakota, and Minnesota.

[6] Average yield, 10.2 bushels per acre. Crop as stated in Government reports; believed to be seriously underestimated.

[7] Small quantities of Calcutta seed imported from 1904 to 1907, not tabulated.

Available records of seed quotations date back to 1855, when Cincinnati was the principal primary market. From 1870 Chicago became the leading seed market, being superseded about 1880 by Duluth-Superior. In 1862, linseed sold as high as $3.25 per bushel. From 1862 to 1874 seed sold at about $2.50. After 1874, prices declined until 1886, when they reached the low level of $1.03. The lowest price recorded was 63 cents in 1897. In 1862, the price varied from $1.25 to $3.25.[1]

Statistics as to the world's crop of flaxseed must be received with caution.[2] Especial uncertainty exists with regard to the Russian crop, which during recent years, however, has averaged about 17,000,000 bushels annually. The average yield in Russia over a period of five years was from 16 to 18 bushels per deciatine (2.7 acres), where the cultivation was practiced solely with a view to seed production. This is equivalent to about 6.3 bushels per acre. Where fiber is raised, or seed and fiber jointly, the yield of seed averages from 688 to 951 pounds per deciatine, or from 5.6 to 6.3 bushels per acre. A considerable amount of seed for sowing is raised, that from the province of Pskoff being especially esteemed, and sometimes commanding a price of nearly $4.00 per bushel. The low yields per acre are attributable to unsuitable climate and soil, the general production of fiber, which has been incompatible with the highest yield of seed, and the depressed condition of agriculture in Russia. The primary markets are Archangel, St. Petersburg, Riga, Odessa, and Taganrog. The principal points of export are Riga, Libau, St. Petersburg, Revel, Rostoff, Odessa, and Nicolaieff; the land frontiers being those of Warsaw, Verybaloff, and Sosnovitz.

The seed is sown in April, May, and early in June. The harvest begins as early as July and as late as the months of August and September, earlier in the South and later in the North. . . . The seed is ready for export in the months of September, October, and November in the South, and from northern and central Russia often not before March of the following year. . . . About $5,000,000 worth of linseed oil is manufactured and consumed annually in Russia, a very small quantity being exported. Oil cake, the product of flaxseed, is exported to the value of about $2,500,000 yearly.

The crop from British India is of more direct consequence to the American crusher. A report by Consul-General Merrill of Calcutta

[1] From pamphlet, "The Linseed Oil Industry," by Spencer Kellogg, Buffalo, 1894.

[2] Among original sources of information, Beerbohm's *Trade List* (London) occupies a deservedly high position.

(Consular Reports, No. 126) states that flax cultivation is usually practiced for the seed only, the fiber being disregarded. The linseed cultivated up to altitudes of 6,000 feet above the sea is oil-yielding. The seed is frequently sown along with wheat or mustard. Owing to this practice, it is difficult to arrive at exact figures as to the area under cultivation. The usual yield is from 4½ to 7 bushels per acre, although in a few districts, like Bustee and Goruckpoor, double this amount is claimed. On the lighter clay lands, the linseed is sown broadcast on standing rice. The latter is harvested as usual, the linseed being left to be reaped about the last of March. The two general grades of seed are the white and the red, a preference being expressed for the former. The arch enemy of the plant is rust. There is only one linseed-oil mill in India, and almost the entire production of seed is exported. In 1881 the exports were about 12,000,000 bushels. In later years the production was about as follows, practically all of which was exported:

1886–'87	18,500,000 bushels
1887–'88	16,500,000 bushels
1888–'89	16,500,000 bushels
1899	17,100,000 bushels
1900	11,800,000 bushels
1901	12,200,000 bushels
1903	13,600,000 bushels
1904	19,200,000 bushels
1905	22,200,000 bushels
1906	13,896,000 bushels (est.)

The exports of linseed are made principally from Bengal, Bombay, and Sind. Seed to the United States goes from the port of Calcutta to New York, San Francisco, and Philadelphia. The primary markets for seed are Bombay, receiving from the provinces Bombay, Oudh, Northwest, Punjab, Central, Rajputana, and Berar; Karachi, supplied from Sindh, Oudh, Northwest, and Punjab; and Calcutta, receiving from all provinces except Bombay, Sindh, Punjab, and Berar.

The Calcutta seed, which is the only grade now received in the United States, is stored in pits dug in the ground and consequently contains a large amount of clayey dust; there is very little other impurity. The seed is full grown and matured and extremely rich in oil, producing a very light oil, well adapted for varnish purposes.

Bombay linseed, a high-priced seed, is extremely clean and difficult

to grind, but makes a fine oil, which, however, cannot readily be "bodied down" by heat.

The cultivation of flax for seed in the Argentine Republic dates back only a few years, but has been rapidly increasing, and the yield per acre is exceptionally good.[1] From 1884 to 1889 the exports ranged only from 1,120,780 to 3,248,160 bushels annually. At present not less than 5 per cent of the total area of soil under cultivation is devoted to flax. The crop is harvested and ready for shipment about March 1. Shipments are made from Buenos Ayres or Rosario.

The statistics of recent Argentine crops are as follows:

Year.	Production.	Home Consumption.	Exports.
	Bushels.	Bushels.	Bushels.
1899	9,680,000	80,000	9,600,000
1900	9,908,000	88,000	9,820,000
1901	17,200,000	2,200,000	15,000,000
1902	16,061,000	1,000,000	15,061,000
1903	33,600,000	?	?
1904	30,000,000	?	?
1905	29,133,000	?	?

The rapid fluctuations in the Argentine crops have until recently made general analysis of international seed distribution impossible. The crop appears now to have reached a maximum. The exports in 1907 were 30,500,000 bushels. The flax-raising provinces are Cordoba, Entre Rios, Santa Fe, and Buenos Ayres. Argentine seed makes a poor varnish oil, the color being apt to be dark or reddish, but this seed produces a good boiled oil.

New York mills, operating on both domestic and imported seeds, have reported cake tests as follows: Domestic, 5.89; Calcutta, 5.34; Argentine, 5.02 per cent. It is difficult to see why better operation should be possible on seed less frequently used.

The following table shows, approximately, the consumption of flaxseed in the principal European countries. This is based on statements of imports and exports, but is not absolutely reliable for the reason that some of the seed imported is merely in transit through various ports on its way to the buyer, and is omitted from the export column.

[1] See report by Consul E. L. Baker, United States Consular Reports, No. 125.

CONSUMPTION OF FLAXSEED IN BUSHELS IN VARIOUS EUROPEAN COUNTRIES.

	England.[1]	France.	Germany.	Holland.	Denmark	(Europe) Total.
1904	20,700,000	6,290,000	18,500,000	9,200,000	?	55,400,000
1903	16,150,000	6,710,000	13,300,000	5,280,000	?	41,100,000
1902	13,100,000	3,705,000	9,700,000	4,850,000	562,000	32,117,000
1901	12,100,000	4,490,000	9,340,000	3,925,000	505,000	30,360,000
1900	12,200,000	4,350,000	10,520,000	3,790,000	583,000	31,443,000
1899	13,650,000	5,310,000	10,440,000	4,820,000	619,000	34,839,000
1898	12,150,000	4,650,000	10,630,000	5,020,000	630,000	33,080,000
1897	14,600,000	6,000,000	10,300,000	4,800,000	714,000	36,414,000

[1] England's average imports from 1893 to 1904 were 15,500,000 bushels annually.

England derives its supply of flaxseed principally from India and the Argentine, only a small part of its requirements coming from Russia, and still less from the United States. Belgium raises an annual crop of about 400,000 bushels, principally consumed at home, but there are no figures available showing the exact consumption. France imports 80 per cent of its seed from India and the Argentine. Germany formerly imported its seed from Russia. At present it derives its supply from the Argentine, India, and Russia. Flaxseed is the most important oil seed consumed in Germany. Holland had about 30,000 acres devoted to the cultivation of flax for seed in 1900, and in addition to this, as noted above, imported large amounts. Linseed constitutes about 50 per cent of its business in oil seeds, and its annual consumption is largely taken care of by the United States crop, its former receipts from Russia and India being now supplanted by what it obtains from the Argentine. The writer's tabulation of the world's approximate average flaxseed statistics would be as given in the following table. It should be remembered that the crops of the past few years have been excessively large.

THE WORLD'S FLAXSEED CROP UNDER AVERAGE CONDITIONS.

Country.	Production.	Exports.	Consumption.	Imports.
	Bushels.	Bushels.	Bushels.	Bushels.
United States	26,000,000	2,000,000	24,100,000	100,000
India	16,000,000	15,000,000	1,000,000	....
Russia	17,000,000	1,425,000	15,575,000	....
Argentine	30,000,000	29,500,000	1,500,000	....
Uruguay	5,000,000	4,800,000	200,000	....
England	....	....	18,800,000	18,800,000
France	500,000	....	7,000,000	6,500,000
Germany	....	....	18,500,000	18,500,000
Holland	300,000	....	7,800,000	7,500,000
Denmark	325,000	....	650,000	325,000
Total	95,125,000	51,725,000	95,125,000	51,725,000

The probable distribution of exports in an average-crop year is as follows:

INTERNATIONAL DISTRIBUTION OF FLAXSEED, IN BUSHELS.

Exports from	Imported by					
	U. S.	England.	France.	Germany.	Holland.	Denmark.
United States	....	....	....	....	2,000,000	....
Russia	....	1,225,000	....	....	....	200,000
India	100,000	7,075,000	2,250,000	5,450,000	....	125,000
Uruguay and Argentine	....	10,500,000	4,250,000	13,050,000	5,500,000	....
Total	100,000	18,800,000	6,500,000	18,500,000	7,500,000	325,000

The northwesterly migration of the crop produced in this country, if continued, must eventually carry it beyond the boundary line into Canada. According to one writer, the crop is now making its last stand. The important economical problem of the utilization of the fiber of the plant must be solved if it is to remain with us as a permanent crop. This is a broader subject than the linseed industry. India, the Argentine, and the United States annually waste the straw of the flax plant, raised solely for its seed. Russia and Belgium save both seed and fiber. Economic considerations lead to the diversity of practice. Good flax fiber can be secured only by pulling the plant before the seeds are mature and while they contain a relatively low percentage of oil. In Europe, flaxseed is expressed primarily for the cake, and a low yield of oil is aimed at. In this country, high yields and rich seed are desired. We therefore mature the plant and throw away annually 900,000,000 pounds of fiber. Meanwhile, the world's production of flax fiber is decreasing.[1] We not only fail to utilize this fiber, but too often we damage it in threshing, so as to totally unfit it for any use other than for the preparation of paper pulp. In 1901, a plant was erected near Fargo, N.D., to make the straw, thus broken, into tow, which was then sent to Niagara Falls and manufactured into paper. The cost of the paper was estimated at about 6 cents per pound, and the product was not uniform in composition or color. Wood pulp produces a paper 40 per cent stronger, which can be

[1] See detailed figures as to the world's production of fiber in the Year Book of the United States Department of Agriculture for 1902.

profitably sold at 6 cents per pound. This disposition of the straw has therefore not been widely extended, and the 450,000 tons annually produced are largely burned, although practically the same product as that which Russia supplies to the flax mills of the world. The finest linen produced is from Belgium, from plants grown for both seed and fiber. Soil selection, fertilizing, rotation of crops, and selection of seed make the difference between Belgian and American results.[1]

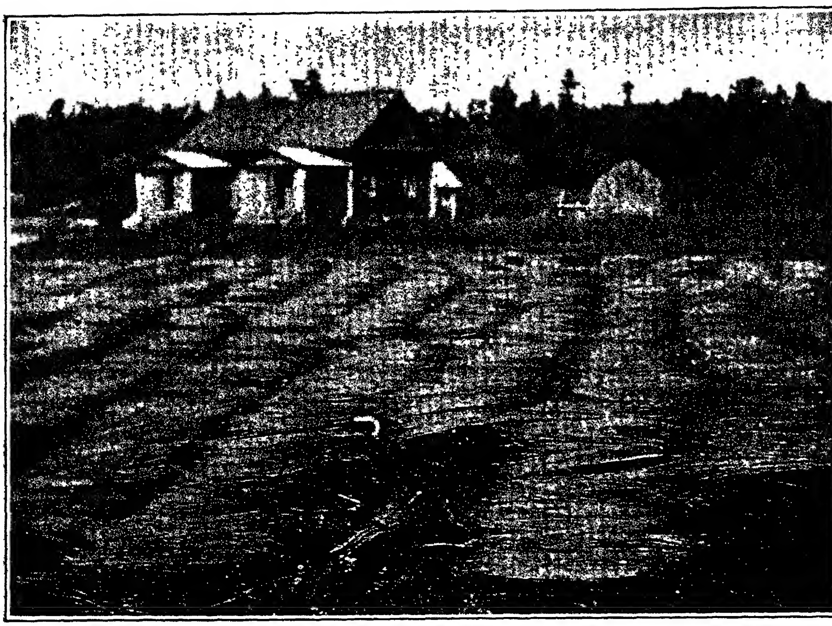


FIG. 53a. — MANNER OF SPREADING FLAX STRAW FOR DEW-RETTING. (Farmers' Bulletin No. 274, United States Department of Agriculture.)

By pulling the plant "when the straw begins to turn yellow and when the foliage within six inches of the ground is drooping," the fiber may be preserved in a condition suitable for weaving into flax. Methods of threshing must be adopted, different from those now in vogue, by which the seed may be separated from the stalk without injuring the latter. After threshing, the stalks are laid in a pool or on a grassy meadow exposed to the dew, for "retting," which frees the fiber from

[1] When raising the flax plant for the fiber, the seed should be planted broadcast and very thickly, using about 3 bushels of seed to the acre, and keeping the ground clear of weeds. This results in a slender, straight plant, free from branches.

the woody and gummy constituents of the stalk. (Fig. 53a.) Much skill is required in properly conducting this operation. The retted stalks are then dried in the sun and carried in bundles to the "scutch" mill, where the stalks are broken or crushed in such a manner as to cause the woody portions to separate from the fiber. This may be done by hand, or by the type of machine shown in Fig. 53b, consisting of pairs of horizontally placed fluted or corrugated rollers, through which the retted stalks are passed endwise.

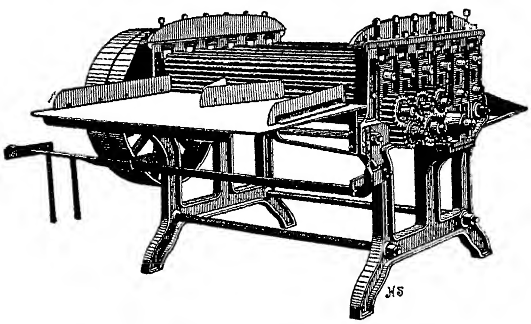


Fig. 53b. — Flax Fiber Breaking Machine.
(Farmers' Bulletin No. 274, United States Department of Agriculture.)

In Belgium, where dual-purpose flax is grown, it is claimed that the revenue from the seed alone is sufficient to cover the cost of cultivation, the revenue from the fiber being net profit. Some progress is being made here. Small industries, such as tow-mills, binder-twine, crash-toweling and bagging factories, have been established in the vicinity of the flax fields, paying for ordinary straw from the threshers from $2 to $3 per ton. It remains for the farmer to keep them supplied with material, involving eventually the growth of flax primarily for its fiber and afterward for the seed. Such a development will be of immense consequence to the linseed industry.

CHAPTER XV.

THE SEED TRADE.

Duluth the primary market. — Duluth and Chicago grading. — Instructions to inspectors. — Inspection from elevator, in bags, etc. — Reports. — Fees. — Seed contracts. — Details regarding inspection of bulk flaxseed received by rail. — Technical terms used in describing flaxseed conditions. — Determination of the impurities in flaxseed. — New York Linseed Association. — The "4 per cent basis sound delivery contract." — Transportation of flaxseed on the Great Lakes. — Shortages. — Freight rates. — The Erie Canal. — Advantages of canal shipments. — Canal bill of lading. — Rail transportation of flaxseed to New York. — Experience with shortages. — Grades of seed worked by the mills. — Milling-in-transit rates. — Effect of speculation in linseed. — Possibility of large loss to crusher. — How the loss is avoided. — Records of market position. — Calculations from assumed conditions. — Foreign linseed quotations.

Duluth-Superior is the primary market for flaxseed in the United States, with Minneapolis a competitor for rail shipments. The Duluth and Chicago gradings of flaxseed do not differ to any great extent.

In the following paragraphs from the regulations, words contained in the description of the Chicago grades but not in the Duluth grading are italicized, while words pertaining to the Duluth inspection only are bracketed.

Regulations for the Inspection and Grading of Flaxseed.

The weight per measured bushel designated for each grade is that of commercially pure seed.

No. 1 Northwestern Flaxseed: Flaxseed to grade No. 1 Northwestern shall be mature, *commercially* sound, dry and sweet. It shall be Northern grown *or shall have the usual characteristics thereof.* The maximum quantity of field, stack, storage or other damaged seed intermixed shall not exceed twelve and one-half per cent. The minimum weight shall be 51 pounds to the measured bushel.

No. 1 Flaxseed: No. 1 flaxseed shall be [Northern grown] *commercially* sound, dry and free from mustiness, and carrying *intermixed* not more than 25 per cent of immature or field, stack, storage or other damaged flaxseed, and weighing not less than 50 pounds to the measured bushel.

The requirements for the remaining grades differ to a somewhat greater extent.

CHICAGO.

Rejected Flaxseed.

All damp and musty flaxseed and that carrying intermixed, immature or field storage or other damaged flaxseed in excess of 25 per cent, and weighing not less than 46½ pounds per measured bushel, shall be graded "Rejected."

No Grade Flaxseed.

Flaxseed that is wet, moldy, warm or in a heating condition, or is in any wise unfit for temporary storage, or weighs less than 46½ pounds, shall be graded "No Grade."

Flaxseed that is smoky, burnt, or intermixed with burnt seed, shall not be known by any grade but shall be inspected in the usual way to determine the percentage of impurities, and shall be posted as "Burnt or Smoky Flax."

DULUTH.

Rejected Flaxseed.

Flaxseed that is binned, burnt, immature, field damaged or musty, and yet not to a degree to be unfit for storage and having a test weight of not less than 47 pounds to the measured bushel, shall be "Rejected."

No Grade Flaxseed.

Flaxseed that is damp, warm, moldy, very musty, or otherwise unfit for storage, or having a weight of less than 47 pounds to the measured bushel, shall be "No Grade."

NOTE. No grain shall in any case be graded above that of the poorest quality found in that lot when it bears evidence of having been plugged or doctored.

At both markets it is required that inspectors must make their reason for grading grain fully known by notations on their books. In case an owner or consignee of seed considers himself aggrieved by the inspection of any car or cars he may obtain a reinspection of the same by giving notice in writing to the Chief District Deputy of the Inspection Department. After such reinspection, should he still be dissatisfied, he may appeal through the Chief Deputy Inspector to the Board of Appeals, in the case of the Duluth market, or to the Board of Trade Committee on Flaxseed Inspection, in the Chicago market.

In sampling for inspection flaxseed received in cars in bulk by railroads, a sampling probe is passed down through the seed at not less than seven different points, equally distributed, and at each point a quantity of seed is taken, aggregating not less than three pounds, which sample is deemed an average and legal sample of the carload.

The inspection of flaxseed from elevator or warehouse to lake transportation is made by passing a grain trier, 12 feet long, through each draught of 1000 bushels after the seed has been elevated to the shipping-scale hopper to be weighed; at each filling of the hopper an equal quantity is drawn. From every ten samples so drawn an average

sample of 3 pounds is taken. On completion of shipment from any elevator or warehouse an equal quantity of flaxseed taken from each of the accumulated 3-pound samples, aggregating 6 pounds, is considered an average sample of the shipment.

In inspecting flaxseed from elevator or warehouse to cars the method of sampling is the same as that when receiving in cars.

The inspection of flaxseed to or from bags is made on samples obtained by taking an equal quantity from each bag as they are filled or emptied, intermixing and taking an average sample of 3 pounds from the lot.

The Inspector of Flaxseed at Chicago is required to report to the Board of Trade: daily, all inspections of seed since his last report; weekly, the amount of flaxseed in store; monthly, the inspected receipts and shipments during the month last past.

The Duluth inspection is under control of the state; for inspection, reinspection, and appeal there are established charges.

In Chicago the fees for inspecting and certifying flaxseed are as follows: For each car or part of car, 75 cents; for each lot in car divided by bulkhead, 50 cents; for each 1000 bushels from elevator or warehouse to lake transportation, 75 cents; for each two-bushel bag, one-half cent; for each four-bushel bag, one cent; for each wagonload, $16\frac{2}{3}$ cents.

All sales of flaxseed are made upon the basis of pure seed; that is to say, seed delivered on contracts may carry impurity or foreign matter, but must contain the sale quantity of pure seed, and for such pure seed only is payment required.

Details Regarding Inspection of Bulk Flaxseed Received by Railroad.

The equipment of an inspector consists of the standard geared screw samplers, $1\frac{1}{4}$ by 44, $1\frac{1}{2}$ by 44, and $1\frac{3}{4}$ by 52, a canvas sack about 18 inches square, sample bags, strings and tags. He is also equipped with a list of car numbers and their corresponding initials, as well as names of the respective consignees, covering receipts of flaxseed since the day previous.

When the inspector has secured entrance to the car to be inspected, he divides the contents, approximately, into seven equal parts, and by placing the sampler on top of the seed and turning the crank with a gradual downward pressure, he extracts a sample of seed for each of these parts.

This manner of operating the sampler passes it through the seed from top to bottom, and draws an equal quantity from every portion of the car. The canvas is then spread under the spout of the sampler and, by turning, the seed is ejected upon it, carefully mixed and placed in the sample bag. This operation is repeated seven times. The

sample bag is securely tied and a tag, stating date, car number, initial, grade, and consignee, is affixed. A duplicate of this tag is tacked to the grain door of the car by the inspector.

In case a car is found to be unevenly loaded, either as to quality, condition, or impurity, thus leaving a doubt in the mind of the inspector as to the correctness of the sample drawn in the usual way, he is required to take such further sample as he may deem necessary under the circumstances. Should he find palpable evidence of attempted fraud or deception in loading the car, such as secreting impurity, or inferior seed, in angles and corners of the car, he makes note of the fact. In case a car is overloaded, or if the bulk seed is covered with bags so as to preclude the drawing of an average sample, the inspector secures the best sample possible and reports the facts in the matter, indicating plainly why an average sample cannot be produced.

The grade of flaxseed is determined by the inspector while the sample is being completed.

If the grade of a car of flaxseed is other than No. 1 or No. 1 N.W., and the average sample does not show positive evidence of having been correctly graded, a special sample is taken of that part of the seed which governs the trade, in order that the consignee may be fully advised. If the grade is changed on account of seed having become wet from an open door or a leaky roof of a car, a remark to this effect, showing cause of grade, and what would have been the grade in the absence of such cause, is noted on the tag.

When snow is found in a car of flaxseed by the inspector in sufficient quantity to affect the grade, the flaxseed is not inspected until the snow has been removed by the railroad company. If the car is wasting or leaking seed, a notation to this effect is made upon the tag and the railroad company is at once notified, as in all matters where liability attaches.

Technical Terms Used in Describing Flaxseed Conditions.

Field Damaged means that the seed is dry and sweet, but intermixed with more than 25 per cent of field-damaged seed.

Light Weight. — The seed is dry and bright, but immature, and weighs less than 50 pounds to the measured bushel.

Musty. — This word is used to indicate that the seed is dry, but has been damp or warm. Otherwise the seed would grade No. 1 N.W. or No. 1.

Damp signifies that there is evidence of moisture. Otherwise the seed would grade No. 1 N.W. or No. 1.

Damp and Damaged. — These words are used to signify that the seed carries intermixed field or storage damaged seed and is in a damp condition.

Damp and Sour signifies that the seed is in the first stage of decomposition.

Damp and Musty signifies that the seed has been warm and is not yet dried.

The following formulae apply to the different conditions of "No Grade" flaxseed:

Excessive Field Damaged indicates that the seed has been partially deprived of its oleaginous quality through long exposure to rain, but was subsequently dried and prepared for market. It weighs less than 46½ pounds to the measured bushel.

Wet indicates a condition of a seed through the influence of moisture which, if this condition were not present, would grade No. 1 N.W. or No. 1.

"*Wet* and *Warm*," or "*Damp* and *Warm*," or "*Musty*," denote flaxseed which would grade No. 1 N.W. or No. 1 were it not out of condition as stated by the terms indicated.

"*Wet* and *Damaged*," "*Wet, Warm* and *Damaged*," or "*Damaged* and *Musty*," are terms which signify that if only the damaged condition existed, without being affected as by the terms indicated, the seed would grade "Rejected."

Smoky Seed is seed intermixed with burnt seed, and it is not inspected.

"*Burnt Seed*," "*Tailings*," and seeds in the last stages of decomposition are not inspected.

Having obtained a reliable sample, the process of estimating the percentage of impurities is to take one pound of the seed, weighed accurately on the standard testing scales, and then to remove the impurity or foreign matter therein as nearly as practicable, employing two sieves with meshes respectively 3 by 16 and 16 by 16. The per cent of impurity thus separated can be weighed on the lower scale of the beam of the test scales. The weight per measured bushel is determined by an arbitrary method of weighing the contents of a cup filled to the brim. After making the determination of per cent of impurities and weight per measured bushel, the sample, having had the impurities returned to it, is tagged and kept on deposit thirty days.

There are special provisions in the Minnesota rules and regulations regarding inspection and weighing in private houses, that is, elevators or warehouses not operated under the provisions of the state law. Such houses are required to pay for inspection and weighing by the State Inspection Department, and are obliged to permit the state weigher to examine and test their scales at any time.

The use of the standard sampling sieves does not satisfactorily remove impurities from flaxseed, and where accurate work is desired it is necessary to resort to hand picking. The following is the method of testing adopted in the chief chemist's office of one crusher:

The original sample is to be carefully quartered down until 500 grams are obtained. In this quartering great care must be observed to pour the linseed upon the center of the pile so that it is evenly distributed in all directions. Use a clean sheet of paper to do the quartering and see that all dirt that settles to the bottom of the quarter removed is carefully brushed up and added to it. Screen the 500-gram sample which is taken for analysis through an 8 or 10 mesh screen until about 50 grams remain on the screen. This 50 grams is to be picked and everything other than linseed is to be set aside and weighed with the first dust. The clean seed obtained at this picking is added to what has passed through the screen. This portion is carefully screened, using a 20-mesh screen, rubbing the seed around in the screen so as to remove any dust that may be attached to it; what passes through this screen is carefully collected and weighed, having added to it the coarse pickings referred to above. This constitutes the "first dust." The partially cleaned linseed is now sampled down, using the tin sampler, until 50 grams are obtained. This is divided by the sampler into two 25-gram weighed portions, which are picked off separately and the impurities weighed separately. Anything in the nature of linseed,

whether dried seed or broken seed, is to be put with the linseed. The following is the form of calculating results:

First dust,	500 grams	
obtained,	5.870 grams =	1.174 per cent
Second picking,	25 grams	
obtained,	0.899 grams	
	0.960 grams	
	1.859 grams	
× 2 =	3.718 =	3.674 per cent
	Total impurities =	4.848 per cent

On second sampling, the results should not disagree more than 60 milligrams. In the cases of some important seeds, the impurities are separated into oleaginous substances and non-oleaginous substances.

Seed brought into this country from abroad, that is, from the Argentine Republic or India,[1] may be purchased under the code of rules of the Linseed Association, a New York organization. These rules are the same as those of the London linseed contract.

The charges for analyzing are divided equally between buyers and sellers, the latter being responsible for the same to the Association.

American flaxseed may be analyzed under the rules of the Association, the charge for the same being at the rate of $1.00 per 1000 bushels, but no analysis is made for a less sum than $5.00.

The London form of contract frequently used for the purchase of La Plata (Argentine) and Calcutta linseed, and often described as the "*Four per cent basis, Sound Delivery Contract,*" provides for delivery of linseed in quarters of 410 or 416 pounds net.[2] The terms of payment are twenty-one days from ship's reporting, cash less 2½ per cent. For purposes of declaration the quantity is calculated on the basis of 2240 pounds English, = 2210 pounds Spanish = 1015 kilos. The contract quantity must be met within 5 per cent.

A cargo arriving damaged by sea or otherwise is to be taken with an allowance fixed by arbitration; 3*d.* per quarter is allowed to the buyer for working-out charges and dues. Samples are taken jointly by buyers' and sellers' agents at port of discharge, either by selecting or opening each bag at buyer's option. A fair sample is taken from same and sealed, and the whole sent together to the Incorporated Oil Seeds Association, who, upon such samples of sound seed only, determine by analysis the quantity and description of the substances other than linseed contained therein. The charge for analyzing is divided between the buyer and the seller. The percentage of admixture having been returned, non-oleaginous substances are considered valueless, and oleaginous as worth half the price of linseed. The agreed standard of admixture is 4 per cent of non-oleaginous substances, and if the amount of admixture exceeds this, the difference is deducted from the selling price, or if less than 4 per cent, is added to the same.

[1] Imported seed is purchased by the English unit, the *quarter* of 410 pounds.

[2] Calcutta linseed prices are usually quoted in sterling money for 410 pounds. At normal rates of exchange, the price of seed in cents per bushel of 56 pounds is 3.3 times the price in shillings per 410 pounds.

The regular form of contract for Calcutta linseed is based on quarters of 410 pounds net, in double gunny bags. Damaged seed is taken with the following allowances:

First class	4 per cent.
Second class	8 per cent.
Third class	12 per cent.

Lower class "damaged" and sweepings are taken at a valuation fixed by arbitration, the expense of same being divided between buyers and sellers. Buyers are obliged to give the sorting orders, and failing to do so must pay for the seed at the contract price. If only single bags are delivered, buyers are allowed one shilling per 410 pounds.

The dock weights are determined by weighing five sound and undamaged bags in every 100 as they rise from the ship, and two in every 100 are emptied to ascertain the tare. Smoky bags are sampled separately and sweepings weighed for sellers' account. Buyers have the option of weighing the bulk of the bags and sweepings at their own expense. Buyers have the option, previous to ship's reporting, of taking the linseed, all weighed at London weights, paying an additional shilling per quarter to the sellers.

In any case where a shipment of seed bearing one mark is divided between two or more buyers the analysis of the sample or samples representing the entire shipment of such mark is considered the final analysis of each delivery.

The transportation of flaxseed on the Great Lakes is based on the standard grain bill of lading modified as follows: that the vessel is responsible only for shortages exceeding one-half bushel per 1000 bushels carried; the vessel to deliver all flaxseed on board, collect freight upon actual outturn, and make no claim for any overrun. Wet or otherwise damaged seed is paid for by the carrier.

During the year 1903 the shortages and overages on lake carriers to Buffalo just balanced each other, so that on the average of all shipments there was neither shortage nor overage. At some other points the record obtained is not as good. Freight rates on the Lakes vary widely from season to season. During one year the rate from Duluth to Buffalo ranged from 3 to 4 cents per bushel, with insurance at one-half cent. The Duluth-Toledo rate was $2\frac{1}{2}$ to $3\frac{1}{2}$ cents; that from Duluth to Chicago was from $2\frac{1}{2}$ to $3\frac{1}{4}$ cents. Seed has been carried to Buffalo at as low a rate as 1 cent. Ordinarily the Buffalo rate is about as low as that to Toledo or Chicago on account of the good opportunity for return cargoes from Buffalo, Conneaut, Ashtabula, and Cleveland. The rail freight rates on seed corresponding to the lake rates above given were, Buffalo to Philadelphia, 4 to 5 cents; to New York, $4\frac{1}{2}$ to $5\frac{1}{2}$ cents; these shipments being accompanied by a shrinkage of nearly one-half of 1 per cent. From Minneapolis to Chicago the rail rate was 8 cents per 100 pounds = $4\frac{1}{2}$ cents per bushel.

The Erie Canal is an important factor in transportation from the standpoint of the New York crusher. While the total canal carriage of grain is only a small percentage of that handled by rail, yet the effect of the opening of the canal is so noticeable on rates that the crusher regards it as an unmixed blessing[1] The great highway of the Lakes is of course of essential importance to the linseed industry in the East. On the Erie Canal each boat carries six horses and two men. Steam-boats carry five men. The trip from Buffalo to New York takes 11 days. The maximum allowable draft is 6 feet. There are no charges of any kind for the use of the canal; any one is free to operate a boat on it. The usual cargo back is sugar; the average freight on the sugar is $1.00 per ton. Each horse-boat pays $30 for towing down the Hudson River from Albany; this takes 36 hours. Canal boatmen claim that they "come out just about even" on a flaxseed rate down of 2¾ cents per bushel, when they get prompt return cargoes at $1.10 per ton.

In the case of a New York mill there are certain conditions which make shipment by canal preferable to shipment by rail, even when the rate is the same or even slightly in favor of rail shipments. On canal boat shipments the mill is allowed for "trimming," that is to say, for shoveling the seed to the elevator leg, $1.50 per 1000 bushels. The outturn on canal boat shipments is guaranteed, while on rail shipments there has been experienced an average loss of over 3 bushels per 1000. With seed at $1.00 this loss plus the credit for "trimming" gives the canal boat an advantage of nearly $5.00 per 1000 bushels. There is a slight expense for towing, which, however, is usually performed by the crusher's boats and is more than offset by other gains. The crusher does his own weighing in the case of the canal boats. There is no question but that canal boat shipments even at the same freight rate are more economical by one-half cent per bushel. One company has always figured that when the rate was not more than three-eighths of a cent in favor of the railroad it would make the shipment preferably by canal.

The canal bill of lading provides that three week days, regardless of weather, exclusive of legal holidays, including day of arrival, shall be allowed consignees to discharge cargo. The boat must be at the usual landing place and notice of arrival given before

[1] The opening of navigation on the canal occurs usually about May 1; on the Hudson River, rather earlier; on the lakes, a few days earlier. The canal closes usually about December 1; the river, a few days later.

12 o'clock noon. Saturday shall count as one-half day only, unless the captain gives notice on arrival of willingness to discharge cargo until 6 P.M. of that day. After the three days so specified consignees are to pay demurrage at the rate of $5.00 per day for each and every day or part of day of such demurrage over the three days until the cargo is fully discharged.

In case the grain becomes heated while in transit, such heating not being caused by leakage of the boat, nor by heat from the boiler or machinery, the carrier shall deliver his entire cargo and pay only for the deficiency caused by heating, exceeding 5 bushels for each 1000 bushels.

In case the cargo is detained by the freezing of the canal while in transit, it is the usual custom that the consignees and owners assume all insurable risks from time of notice to such consignees that boat is stopped until delivery of cargo at point of destination. Interest on all advance charges from time of such notice are paid with and as part of such charges.

The customary rule in rail transportation of any grain is that no carrier shall be liable for differences in weights or for shrinkage of any grain or seed carried in bulk. This is occasionally modified. On shipments of wheat, corn, and oats via all rail to carriers' elevators on the Atlantic seaboard, weights are guaranteed. This is of no valuable application, however, to flaxseed, as there is practically no seed thus shipped. By agreement with the New York Produce Exchange the trunk lines between Buffalo and New York guarantee the outturn of graded grains under certain conditions, but there is another existing and discriminating clause exempting flaxseed and ungraded grains generally from guarantee as to outturn. Many efforts have been made to secure such a guarantee from the carriers, but without success, the latter claiming that the carrying of flaxseed at regular grain rates was in itself a concession. Flaxseed shippers have always contended and argued that flaxseed should be carried at the same rate as wheat. There is a general impression among carriers that there is necessarily a greater loss in handling flaxseed than in handling other grains.

During the past two years the average shortage on canal shipments has amounted to .71 bushel per 1000 on the entire run from Buffalo to New York mills, being only a little more than half the average shortage on the six-mile trip from railroad elevator to mill when the railroads handle the seed.

The transportation of flaxseed from Buffalo to New York, with respect to demurrage, etc., is wholly regulated by agreement of the carriers with the New York Produce Exchange, the rules being published as a part of the Produce Exchange Annual Report.

Rule 8 of the Exchange's agreement with the railroads for the trans-

portation of grain provides that "claims for boat shortages on flaxseed . . . whether all-rail or ex-lake, will not be allowed." The Regulations of Inspection of the Exchange provide for inspection, and establish fees for such service; but these regulations do not apply to flax, which is purchased on primary-market grades and shipped in the name of the crusher. The Exchange also establishes the fees for towing canal boats and for railroad lighterage.

Most Eastern crushers run largely on No. 1 or No. 1 Northwestern seed. A small amount of rejected seed or screenings is occasionally used.

Crushers have frequently endeavored to obtain "Milling-in-Transit" freight rates on flaxseed, but without general success. Such rates take cognizance of the fact that the oil cake is a residual form of the seed, and the rate for the seed includes the freight on the cake to its seaboard destination. They have been largely granted to flour mills, a mill in Albany, N.Y., for example, getting a freight rate on wheat from Buffalo to New York, and having the privilege of milling the wheat into flour during the transit. An objection to the application of such rates to linseed is that the oil cake does not represent the entire product of the seed. A similar complication enters, however, into the balancing of flour against wheat shipments, some of the former undoubtedly being diverted; but this complication does not appear to be serious.

The basis of the linseed industry is the seed crop; and this, like all agricultural products, is subject to serious fluctuations and to the arbitrary influences of speculation. The first linseed crushers were primarily speculators in flaxseed. Many of them continued in the latter industry after outgrowing the former. An open and unhampered seed market is of vital importance to the manufacturer and consumer of oil. No crusher can succeed unless he is a shrewd buyer and seller of seed. The fluctuations of the market are always his first concern. A few seconds of time, when prices are varying widely, may wipe out his profits. In the absence of control of these fluctuations, the most essential thing is to provide for their close observation and for a constant alignment of selling policy with them.

The crusher must buy seed in order to sell oil and cake. If the price of oil is such as compared with the price of seed that there is no profit in crushing, he may shut down his mill or run on his stored seed or possibly buy oil in anticipation of an advance. If he has accumulated

stocks of seed at a low price, he may find more profit in selling his seed during a bull market than in manufacturing it into oil. These illustrations are only two of the large number which might be given showing why, at times, the crusher must *sell* seed or *buy* oil. He is further forced to a speculative attitude by the extreme manipulations to which the seed market has been subjected. The flaxseed crop is small and its products are necessities. It is therefore an easy matter to "corner" the market, and from the statistics given in Chapter XIV it may be noted that one hundred million dollars would suffice to buy outright the world's annual crop of flaxseed. The crusher must therefore be a speculator to the extent of constantly trading in the seed market in accordance with its natural or manipulated fluctuations. As a manufacturer and dealer, he must also know the relation between his purchases and sales, his consumption and his products. In order to record these relations, he must determine how each successive purchase or sale of flaxseed affects the total quantity of seed he owns or owes, and at what average price this net total quantity is held. He then compares his position with the ruling market quotations. If he owns 1,000,000 bushels of seed at an average price of 98 cents and the ruling quotations are 99 cents, he is safe, but if the ruling quotation is 96 cents, he is a loser to the extent of two cents a bushel on all of the seed he owns. If he anticipates a future rise in the price of seed, he may hold his stock, or even buy more, reducing his average price, but if the rise does not come, he is sure to lose. If he owes the market or has contracted to sell to consumers 3,000,000 gallons of oil at 40 cents per gallon, and the ruling price of oil in consequence of the decline in seed value has fallen to 39 cents, his customer must lose, and he may gain, 1 cent per gallon on 3,000,000 gallons, or more than enough to offset the loss indicated from his position on the seed market. Suppose, however, that the markets have been fluctuating violently and that he has contracted to sell oil at 40 cents, the ruling price now being 42 cents; he then faces a loss on the oil market as well as on the seed market. This, however, may represent a loss of *possible* profit only, since it is reasonable to assume that in making a 40-cent price on future oil he had the seed in sight.

Let us consider how these conditions are dealt with in actual practice. Assume that the crusher has in stock or on contract, for quick delivery, 1,000,000 bushels of seed at an average price of $1.00 at the primary market. Suppose that the market price of seed is $1.03, the price of oil

39 to 40 cents, the crusher's working cost from seed at the primary market to bulk oil being 20 cents. The cost of producing oil, with cake at an assumed value of $20, is then $.3277 per gallon.[1] By selling oil at 40 cents, the crusher may gain $.0723 per gallon or 18.3 cents per bushel; by selling seed, he may gain 3 cents per bushel. He may make 3 cents per bushel on oil sales, while marketing his oil at as low a figure as $\left(\$.3277 + \$.03\frac{7.5}{19}\right) = \$.3395$ per gallon. Suppose now that "future" seed, i.e., seed for delivery later in the season, is selling at 98 cents per bushel. Future oil will be, presumably, offered at a correspondingly low figure; and unless the crusher disposes of the oil from his 1,000,000-bushel stock at once, he may have to sell it later on in competition with oil produced from 98-cent seed. Probably he will sell all the oil that he can, and "hedge" by selling "spot" and buying "future" seed.

The crusher buys, we will say, some future seed at 98 cents and sells some spot seed at $1.02 and $1.03. The result of his day's trades is to increase his stock of seed to 1,140,000 bushels, and to decrease the average price of the seed to $.9915. Meanwhile he is trading in oil. He has a stock, say, of 1,000,000 gallons, which cost him $.3277 per gallon. He buys a small parcel of second-hand oil at 35 cents, and sells 350,000 gallons at the prices given. The profit on the oil which he sells makes his remaining stock of oil "stand him" less than it originally cost, or $.2946 per gallon, which is $.0291 less than oil can be produced for from the seed which he owns. His day's transactions on oil have apparently netted, therefore, $20,370. He has depleted his oil stock 300,000 gallons; for which he has received a net return of $121,500, or $.405 per gallon. The seed necessary to replace the oil lost is $300,000 \times 7\frac{1}{2} \div 19 = 118,400$ bushels; and as he has purchased 140,000 bushels, he has not oversold. The record would be more complete if the cake trades were analyzed in the same manner.

Such an analysis as this, made daily, is necessary to show the crusher where he stands with respect to the market. If he summarizes in this way his net purchases of seed, his net sales of oil and cake, the average prices, and the effect of the day's trades on his total stocks, then he is in a position to bargain intelligently, bearing in mind at all times the capacity of his mill for crushing and for storage and the conditions of transportation which affect the delivery of his seed.

[1] See Table, Appendix.

CHAPTER XVI.

CHEMICAL CHARACTERISTICS OF LINSEED OIL.

References.—Importance.—Drying oils.—Composition of linseed oil.—Properties.—"Breaking."—Chemistry of drying.—Characteristics of pure raw American old-process oil.—Physical and chemical constants.—Standard specification for raw linseed oil.—Rosin test.—Livache and Bishop silica drying test.—Precipitated lead drying test.—Saponification number.—Soluble and insoluble acids.—Iodine absorption.—Hanus method, Wijs method.—Application to the determination of rosin.—Maumené test.—Minor tests.—Acetyl values.—Specific temperature numbers.—Usual adulterants.—Rosin oils.—Hydrocarbon oils.—Corn oil.—Substitute oils.—Mixtures.—New York law regarding adulteration.—China wood oil.

THE chemistry of linseed oil has been treated quite comprehensively by various writers, the most complete work being, probably, Lewkowitsch's adaptation of Benedikt's *Analyse der Fette*, the *Chemical Analysis of Oils, Fats, and Waxes*, London, 1898. This is now scarcely up to date. Professor Olsen's *Quantitative Chemical Analysis* (D. Van Nostrand Company, 1904) deals briefly but broadly with the usual physical and chemical tests. Bulletins Nos. 65 and 81 of the United States Department of Agriculture give useful recent data on oil analysis in general, describing in detail the determination of standard constants and the detection of the constituents in mixtures of oils. Mulder was probably the pioneer in oil chemistry in general. The analysis of fats and oils is a broad subject, worthy of exhaustive treatment in itself. Its importance to the crusher and consumer of linseed oil lies in the facilities it affords for the detection of adulteration. Probably no crusher at the present day ever intentionally adulterates his oil. Sophistication, if practiced at all, is practiced by others than manufacturers, and only at times when the price of oil is high. Its effect is always harmful, and its existence not always easy to determine by superficial inspection.

Linseed oil is classed with the drying oils. All fixed oils are glycerides, i. e., compounds of glycerine with fatty acids. A drying oil is one which solidifies to an elastic substance upon exposure to the atmosphere at ordinary temperatures. All such oils contain fatty acids analogous to that in linseed oil, i.e., linoleic acid. The drying property is due to the

presence of the linoleic[1] or similar acids, which are found in poppy, walnut, hemp, tung, and castor oils, as well as linseed. The glyceride of linoleic acid is linolein; the corresponding glycerides of oleic, palmitic, and other acids make the principal remaining constituents of the oil. Of the total fatty acids present, about 85 per cent impart distinct drying properties. The acids themselves do not dry, but only the resulting glycerides — linolein, and analogous glycerides, olein, palmitin, myristin, etc.

Besides the glycerides, linseed oil contains traces of coloring matters, including xanthrophyll and chlorophyll (yellow), chlorophyll (green), and erythrophyll (red). Small amounts of butyric, valerianic, and caproic acids are also present.

The physical and chemical constants are given differently by various writers, probably on account of the use of treated or cold-pressed rather than ordinary raw oils in many of the experiments.[2] The raw oil of commerce is not cold-pressed oil, and will not give the same results in the laboratory as the latter. The former has a bland taste and sweet odor. Its specific gravity at 60 degrees F. varies from .928 to .940, and its volume is therefore about 29.7 cubic inches per pound at 60 degrees F. One United States standard gallon contains about 7.8 pounds, but the oil is always sold by the commercial gallon of 7½ pounds. Its specific heat is .3. It is soluble in 5 parts of boiling absolute alcohol, in ether, carbon disulphide, benzine, etc. It is solidified by the action of chloride of sulphur, the jelly-like mass obtained being sometimes used as a rubber substitute. The coefficient of expansion is .00045 per degree F. It does not polarize light. Unless taken directly from the presses while hot, it contains very little moisture.[3] The ultimate analysis of the oil shows carbon 75.27, hydrogen 10.88, oxygen 13.85 parts in 100.[4] While

[1] Hazura has identified analogous acids which he names linolenic and isolinolenic.

[2] The origin of the seed also appears to affect the chemical and physical characteristics of the oil. Thus, there is a progressive (though slight) improvement in oils from seeds derived respectively from the American Northwest, India, Morocco, Holland, and the Baltic, evidenced by an increasing iodine absorption value, etc. These differences bear no relation to any differences in percentage of oil from the seed. According to Maire, oil from American seed is slightly inferior to oils from imported seeds because the American seed is not allowed to become fully mature.

[3] One sample of commercial raw oil was exposed to the air for eight days, during which time a small portion was taken daily for the determination of moisture. The results gave the following percentages: .05, .06, .04, .06, .07, .05, .04, .053. The presence of moisture up to one-half of one per cent would evidence freshness only, and would not in general detract from the working qualities.

[4] Cold-pressed oil gives carbon 78.11, hydrogen 10.86, oxygen 11.03.

a superficial examination is insufficient to detect adulteration, if an oil satisfies certain crude tests, easily applied by any intelligent person, it may usually be presumed to be pure. The taste, smell, and color are characteristic, while the consistency, specific gravity, and behavior under heat may be easily checked against those of standard samples of known purity. The most characteristic of all of the properties of the oil is that of "breaking" when heated. Hot-pressed oil (not too old) when raised to a temperature a little above 400 degrees F. shows a sudden and distinct separation of a cloudy gelatinous mass. This phenomenon is known as "breaking." Some other oils (corn oil, for example) will break, but in a different way and at different temperatures. Cold-pressed linseed oil from unground flaxseed does not break, nor does hot-pressed oil if very old — say a year or more. On account of "breaking," raw oil is not suitable for applications in which high temperatures are attained, as in varnish making. Few treatises on oil chemistry attach sufficient importance to the "breaking" as a characteristic behavior of linseed oil.[1] Upon complete ignition, linseed oil leaves a tarry residue. Restricted combustion gives a thick brown residue known as "bird lime." Cold-pressed oil is characterized by a lighter color and a less perceptible taste and smell than those of ordinary raw oil. It is used in some countries as a table oil. New-process oil (see page 176) differs somewhat in color, and more slightly in chemical reactions, from old-process oil.

Most of the applications of linseed oil depend upon its characteristic drying property. The solidified oxidized linolein resulting from the drying is called linoxyn. This is analogous with similar oxidation products of the other glycerides in the oil. It differs from linolein in containing a larger proportion of oxygen. It forms a dry elastic mass, yellow or brown in color, resembling india-rubber in its properties. There is some question as to whether the glycerine contained in the linolein is set free during the drying, as carbon dioxide and water. The weight of evidence favors the theory that the glycerine for the most part remains in the dried film, along with a large proportion of added oxygen. The absorption of oxygen in drying may be observed by causing a thin layer of linseed oil to dry while contained in a vessel placed mouth downward over a bath of mercury. The volume of air confined above

[1] As to the cause of "breaking," formerly thought to be due to the coagulation of albuminous matter, G. W. Thompson has shown that it follows the separation of various phosphates, which will settle out if the oil is allowed to age. Very old oil, therefore, will not break.

the mercury will decrease as drying progresses. The weight of oil will increase, though not exactly in proportion to the oxygen taken in from the air; and the residual air above the mercury will be found to contain traces of carbon dioxide and an excessive amount of nitrogen, with, possibly, very small amounts of water and volatile acids. According to Toch,[1] the amount of carbon dioxide evolved by the oil in drying in no case exceeds eight-tenths of one per cent, while the absorption of oxygen may be as much as 19 per cent. He concludes that the amount of carbon dioxide given off by linseed oil under normal conditions "cannot be very great." This is of much practical importance. Carbon dioxide acts as a rust producer on iron or steel, and if it were liberated in large quantities by linseed oil, that substance would damage rather than protect iron work when applied to such work in the form of paint.

Glycerine may be liberated from linseed oil by suitable treatment, as will be further described. Saponification may be produced, in fact, by the action of water alone, which frees the glycerine and "hydrolizes" the oil, the resulting product being porous and non-waterproof. If, however, the oil is combined with a suitable base, like the ferro-ferricyanide of iron, the resulting film is not a mixture of glycerine and linoleic acid, but a complex compound of the various fatty acids with iron, which is highly elastic and waterproof. The soaps produced by the saponification of linolein are linoleates, some of which are soluble and some insoluble. With oxide of lead, for example, lead linoleate is formed. This dries, forming linoxate of lead.

A specification for linseed oil should be drawn up with great care. Even the precise limits of specific gravity of pure oil are not definitely known. Many widely quoted figures for the physical and chemical properties are based on old experiments made on raw, boiled, or treated oils produced in various ways from different kinds of seed and in various stages of age and sedimentation. They are often not comparable with one another. Some of the chemical tests to be described require extremely nice manipulation, and even in the hands of chemists the results of the operations are not always to be relied upon. The following are the distinguishing characteristics, so far as known, of pure raw linseed oil. The constants given do not necessarily apply to treated oils, and they are based on experiments with oils from American, Argentine, and Calcutta seeds, made by the old process only.

[1] *Chemistry and Technology of Mixed Paints.* D. Van Nostrand Company.

Color: a sample should be compared with a sample of oil known to be pure, by transmitted light through several equal thicknesses of layer. In cold weather, the oils should be warmed before examining. Unusual darkness suggests the presence of rosin or heavy mineral oil.

Taste: should be not disagreeable; not nauseating; bland rather than sweet; leaving no unpleasant permanent flavor.

Odor: this is unmistakable, but varies with the age of the oil. When rubbed between the hands, a whitish lather should form, the temperature should rise, and the mealy flavor become more pronounced.

Bloom: none. By dropping a small quantity of the oil on a strip of glass painted with lampblack, the presence of mineral or rosin oils is indicated by a blue or gray coloration in strong sunlight.

Specific gravity: from .928 to .940, as already stated.

Freezing: linseed oil has an extremely low freezing point, viz., 18 degrees F. below zero. Fish oil freezes at 32 degrees F., cotton-seed oil at 6 degrees, rosin oil at 20 degrees, heavy mineral oils at about 0 degrees. The only oil that congeals at a lower point than linseed is walnut oil.

Moisture: even when very fresh, not more than one-half of one per cent of the weight should be lost when the oil is heated for three hours at 212 degrees F.

Foots: not more than one per cent of sediment should appear from oil which has been kept in a quiescent state between 50 and 80 degrees F. for 96 hours.

Breaking: this action has been discussed. It should occur between 400 and 450 degrees F., and the coagulated mass should be of about the same color as the oil — usually somewhat streaked.

Flash point: not below 500 degrees F., usually about 525 degrees. A pressed-tin cup or other dish that will stand heat is placed on a sand plate over an oil or gas heater and gradually warmed while stirring with a thermometer having a range up to 700 degrees F. As the oil is heated, the flame from a small taper is occasionally brought into contact with its surface. When benzene or turpentine is present, the oil will flash at a temperature but little above that of the room. Rosin oil and the heavier petroleum oils have a higher flash point, which is, however, still lower than that of linseed. The pure oil should take fire and burn quietly but with an intensely irritating odor at from 625 to 640 degrees.

Drying: comparison of the time of drying on glass with that of a standard sample will often show impurity. If the sample dries "tacky,"

rosin oil may be present. Only pure oil will stand rubbing with the finger while drying without peeling off. The silica drying test or Livache's precipitated lead test may also be applied.

Refraction: the refractive index of pure linseed oil varies from 1.4835 at 15 degrees C. to 1.466 at 60 degrees C.[1] The refractometric deviation of linseed and other oils is tabulated by Livache.[2]

Constants: the standard physical and chemical tests, some of which are described later, give the following results on pure raw oil:

Heat of bromination from 29.8 to 32.5 degrees C.[3] The bromine thermal value is the highest obtained for any oil. The bromine absorption figure (per cent absorbed) is from 105 to 115. Rosin oil absorbs 90 to 200, turpentine about 265, rosin from 135 to 165 per cent, while menhaden oil gives the same absorption as linseed. All other oils show less absorption. The bromine addition figure is from 100 to 110—higher than that of any probable adulterant excepting turpentine. The bromine substitution figure is less than 7 — about that obtained by mineral oils, menhaden oil, corn oil, or cotton-seed oil. Rosin, rosin oil, turpentine, and benzene give higher figures.[4]

The Maumené test gives temperatures of from 100 to 111 degrees C. Age increases the Maumené value. With the exception of some fish oils, no other oil gives as great a rise of temperature.

The iodine absorption figure is from 170 to 187 per cent. This is the highest figure given by any of the fatty oils. Exposure of the oil to the air (oxidation) decreases the absorption of iodine. The Baltic seed produces an oil having an excessively high iodine value. Early observers reported figures as low as 148 per cent; these are attributed by Lewkowitsch to the use of insufficient excess of iodine.

The acid value is quite variable, but usually less than 7. Rosin shows an acid figure of 155 to 165,[5] while mineral oils give zero.

The saponification value is from 187 to 197 (milligrams of caustic potash). The oil should contain not more than $1\frac{1}{4}$ per cent of unsaponifiable matter. Thomson and Ballantyne found the percentage to range

[1] Lewkowitsch.

[2] *Varnishes, Oil Crushing, etc.* (Scott, Greenwood & Co.) The bulletins of the Department of Agriculture, already referred to, describe the method of determination of the refractive index.

[3] Lewkowitsch.

[4] McIlhiney: Report to the Commissioner of Agriculture of the State of New York. Albany, 1901.

[5] McIlhiney, *op. cit.*

from 1.09 to 1.29. The method of determination is fully given in Bulletin No. 81 of the Bureau of Chemistry, United States Department of Agriculture.

Linseed oil does not solidify under the elaidin test. Its acetyl value is from 6.85 to 8.7.

Proposed Standard Specification for Raw Linseed Oil.

The oil shall be that obtained [by expression[1]] from clean North American or Argentine flaxseed. It must be of standard clear amber color at 65° F., and shall have a specific gravity between .928 and .940 at 60° F. It must not freeze at a temperature higher than 15° F. below zero. It shall not contain more than one-half of one per cent of moisture, nor more than one per cent of foots. It must not flash below 500° F., nor burn below 600° F. It must show a rise in temperature of not less than 100 degrees in the Maumené test; an iodine absorption of from 170 to 187 per cent; and must not contain more than 1½ per cent unsaponifiable.

Brief outlines of the methods for making the more common standard tests are given below. The preliminary examination usually comprises a few simple operations which determine qualitatively the probable nature of the oil. These are followed by the more definite quantitative measurements where the necessary equipment and operators are available. The first class of operations includes a test for rosin and two drying tests.

Rosin Test.

Mix by shaking together quickly, equal volumes of the oil and of grain alcohol. Allow to stand for one hour, then decant the alcoholic layer and into the decanted solution drop from two to five drops of lead acetate. Allow to stand for six hours. The presence of rosin is indicated by a permanent white sediment.

The Livache and Bishop Silica Drying Test.[2] *(Hooker.)*

About 10 grams (150 grains) of finely powdered silica are placed in a small glass petri dish, together with a short glass stirring rod. The whole is carefully weighed and about one gram (15 grains) of the oil to be tested is run in and the whole carefully stirred without loss. The weight is again taken, the difference giving the amount of oil taken. The dish is now placed where it will receive a change of air and light but be protected from dust, and is reweighed at definite periods, the change being noted. With a slow-drying raw oil, the silica used is specially prepared by mixing it dry and grinding in very carefully one-half per cent each of red lead and black oxide of manganese. This addition materially hastens the drying of the oil and thus shortens the period of observation. On this basis raw oil has made its full gain before any change in weight is noticed with corn oil, for example; although this last oil on long-continued exposure makes some gain under this treatment, raw linseed oil gains from 15 per cent to 18 per cent; boiled oil from 14 to 17 per cent, unless from long keeping it has become fatty. (As an example

[1] May be omitted if new-process oil is acceptable.

[2] According to A. H. Sabin (paper before the New York section of the Society of Chemical Industry, 1906) there appear some unexplained irregularities in the increases in weight of reputedly pure oils tested by this and similar methods.

of this, a most excellent lead manganese boiled oil, which showed an original gain of 15.8 per cent in drying and 1.25 per cent of free fatty acid, after keeping for 13 months in a loosely corked bottle so that it had become distinctly fatty, sufficiently so to cause trouble in painting, then showed a maximum gain of but 10.6 per cent and had developed nearly 5 per cent of free fatty acids.)

Adulterated oils generally show less gain than pure oils, and if a volatile product is present, as is common, the oil frequently shows a loss in weight within a few hours.

Livache Precipitated Lead Drying Test.

This is made by weighing out about one gram of precipitated lead on a watch glass, then slowly adding one-half gram of oil at various points over the surface of the lead. The lead is prepared by precipitating a lead salt on a zinc plate, then washing and drying *in vacuo*. The oil dries by absorbing oxygen, and the increase of weight is a measure of the drying quality of the oil. According to Livache, the increase in weight in two days, with pure linseed oil, was 14.3 per cent, its nearest competitor showing only about half this increase. This test can be easily made by anyone after a slight amount of practice.

Of the more definite quantitative tests, those most important are the determination of the saponification number, the iodine absorption, and the rise in temperature with sulphuric acid (Maumené test). Special tests for boiled oil and other special oils will be discussed under the proper headings for these products.

The saponification number indicates the number of milligrams of caustic potash necessary to completely neutralize the acids present in one gram of oil. When an oil is treated with an alcoholic solution of caustic potash, the glycerides are broken up and the acids are saponified by the potash. As the acids present in various oils differ in molecular weight and basicity, varying amounts of potash are required to neutralize various oils, the amount necessary for any given oil being, however, fairly constant. As the mineral oils, benzene and turpentine, are not saponifiable, their saponification number is zero. The number for rosin oil is less than 20; for menhaden oil, about 189; for corn oil, about 189; for rosin, 175 to 195. The following values are given by Olsen.[1]

Butter	216–233	Cod-liver oil	175–206
Oleomargarine	192–200	Sperm oil	123–147
Cocoanut oil	253–270	Cocoa butter	192–202
Lard	193–200	Sesame oil	187–193
Olive oil	187–203	Wool fat	98–127
Niger oil	189–191	Almond oil	187.9–195.5
Cotton-seed oil	191–196	Peanut oil	185.6–197
Colza or rape oil	175–179	Palm oil	202
Castor oil	176–186	Beeswax	90–100

Raw linseed oil, 187 to 197.[2]

[1] *Quantitative Chemical Analysis.* D. Van Nostrand Company.
[2] China wood oil, 194.

Determination of Saponification Number.[1]

The saponification number and soluble and insoluble acids are determined in one sample by the following method:

(a) preparation of reagents.

Standard sodium hydroxide solution.— A decinormal solution of sodium hydroxide is used. Each cubic centimeter contains 0.0040 gram of sodium hydroxide and neutralizes 0.0088 gram of butyric acid ($C_4H_8O_2$).[2]

Alcoholic potash solution. — Dissolve 40 grams of good potassium hydroxide in one liter of 95 per cent redistilled alcohol.[3] The solution must be clear and the potassium hydroxide free from carbonates.

Standard acid solution.—Prepare accurately a half-normal solution of hydrochloric acid.[2]

Indicator. — Dissolve one gram of phenolphthalein in 100 c.c. of 95 per cent alcohol.

(b) weighing of sample.

The saponification is carried on in a wide-mouth Erlenmeyer flask holding from 250 to 300 c.c. These are cleaned by thoroughly washing with water, alcohol, and ether, wiped perfectly dry on the outside, and heated for one hour at the temperature of boiling water. The flasks are then placed on a tray, covered with a silk handkerchief, and allowed to cool. They must not be wiped with a silk handkerchief within fifteen or twenty minutes of the time they are weighed.

About 5 grams of the oil, which has been filtered, is run in by means of a pipette, and after cooling the flask and contents are again weighed.

(c) koetstorfer or saponification number.[4]

Measure 50 c.c. of the alcoholic potash solution into the flask by means of a burette or pipette, which is allowed to drain a definite time. Connect the flask with a reflux[5] condenser and boil for thirty minutes, until the oil is completely saponified. Cool the flask and titrate with half-normal hydrochloric acid, using phenolphthalein as indicator. The Koetstorfer number (milligrams of potassium hydroxide required to saponify one gram of oil) is obtained by subtracting the number of cubic centimeters of hydrochloric acid used to neutralize the excess of alkali after saponification from the number of cubic centimeters necessary to neutralize the 50 c.c. of alkali added, multiplying the result by 28.06 (mg. potassium hydroxide per cubic centimeter) and dividing by the number of grams of oil used.

To calculate the "saponification equivalent," divide 56,100 by the saponification number, the saponification equivalent being the number of grams of oil saponified by one equivalent of potassium hydroxide, or 56.1 grams. There is no advantage in stating it in this way, and for the sake of uniformity, the Koetstorfer number being more generally used, it would seem advisable to adopt it.

[1] U. S. Dept. of Agr., Div. of Chem., Bul. 46 revised, p. 47.

[2] These standard normal solutions may be purchased ready for use from the larger chemical supply houses.

[3] The alcohol should be redistilled from potassium hydroxide on which it has been standing for some time, or with which it has been boiled for some time, using a reflux condenser.

[4] Chiefly of value in oil work in the detection of rape-oil, resin, and paraffin products.

[5] Almost any sort of a reflux condenser will do. A small funnel placed in the mouth of the flask is perfectly satisfactory and very convenient.

(*d*) SOLUBLE ACIDS.

Place the flask on a water bath and evaporate the alcohol. Add such an amount of half-normal hydrochloric acid that its volume plus the amount used in titrating for the saponification number will be one cubic centimeter in excess of the amount required to neutralize the 50 c.c. of alcoholic potash added. Connect the flask with a condensing tube three feet long made of small glass tubing and place it on the steam bath until the separated fatty acids form a clear stratum on the upper surface of the liquid. Fill the flask to the neck with hot water and cool it in ice water until the cake of fatty acids is thoroughly hardened. Pour the liquid contents of the flask through a dry weighed filter into a liter flask, taking care not to break the cake. Fill the flask again with hot water, set on the steam bath until the fatty acids collect at the surface, cool by immersing in ice water, and filter the liquid again into the liter flask. Repeat this treatment with hot water, followed by cooling and filtration of the wash water three times, collecting the washings in the liter flask, and titrate with decinormal alkali, using phenolphthalein as indicator.

The number of cubic centimeters of decinormal alkali used in this titration diminished by five (corresponding to the excess of one centimeter of half-normal acid) and multiplied by 0.0088 gives the weight of acid in the amount of oil saponified; dividing this by the weight of oil taken gives the percentage of soluble acids.

The determination of iodine absorption may in some cases serve to identify an oil. A measured amount of iodine solution is allowed to act on the oil, under certain established conditions. A considerable proportion of the iodine (bromine may be used as an alternative) will be found to have been absorbed by the fatty acids. The values for this constant as reported by various observers do not agree closely, largely on account of inaccuracies of early methods of determination. Considering results obtained by the Wijs or Hanus methods only, the following are the usual iodine absorption values.[1]

Butter	30.6 to 36.2	Oleo oil	43.3 to 43.5
Cocoanut oil	8.6 to 9.05	Oleomargarine	52.0 to 66.0
Corn oil	119.6 to 129.2	Olive oil	79.9 to 91.4
Cotton-seed oil	105.2 to 107.8	Peanut oil	87.2 to 99.0
Konut	6.4 to 6.43	Poppy oil	119.6 to 139.1
Lard oil	56.9 to 74.5	Rape oil	98.8 to 105.7
Magnolia oil	74.0 to 79.4	Sesame oil	106.5 to 111.7
Mustard oil	103.8 to 118.5	Sunflower oil	107.7 to 119.

Raw linseed oil 170 to 187.[2]

The original method for determining iodine absorption, that of Hübl, is described in Bulletin No. 65 of the United States Department of Agri-

[1] Olsen, *op. cit.*, pp. 416, 417. McIlhiney (*op. cit.*) gives for mineral oils less than 15; rosin oil, 40 to 60; menhaden oil, 160 to 180; rosin, 140 to 160. These values were obtained by the Hübl method.

[2] China wood oil, by the Hübl method, gives 160.

culture, previously cited. This has now been generally superseded by the Wijs or Hanus methods, involving the following procedures:

DETERMINATION OF IODINE ABSORPTION — *Hanus Method.*[1]

(a) PREPARATION OF REAGENTS.

1. *Iodine solution.* — (a) Dissolve 13.2 grams iodine in 1000 c.c. glacial acetic 99.5 per cent acid (showing no reduction with bichromate and H_2SO_4); add enough bromine to double the halogen content determined by titration — 3 c.c. of bromine is about the proper amount. The iodine may be dissolved by the aid of heat, but the solution should be cold when bromine is added.

2. *Decinormal sodium thiosulphate solution.*— Dissolve 24.8 grams of chemically pure sodium thiosulphate, freshly pulverized as finely as possible and dried between filter or blotting paper, and dilute with water to one liter at the temperature at which the titrations are to be made.

3. *Starch paste.* — One gram of starch is boiled in 200 c.c. of distilled water for 10 minutes and cooled to room temperature.

4. *Solution of potassium iodide.* — One hundred and fifty grams of potassium iodide are dissolved in water and made up to one liter.

5. *Decinormal potassium bichromate.* — Dissolve 4.9066 grams of chemically pure potassium bichromate in distilled water, and make the volume up to one liter at the temperature at which the titrations are to be made. The bichromate solution should be checked against pure iron.

(b) DETERMINATION.

1. *Standardizing the sodium thiosulphate solution.* — Place 20 c.c. of the potassium bichromate solution, to which has been added 10 c.c. of the solution of potassium iodide, in a glass-stoppered flask. Add to this 5 c.c. of strong hydrochloric acid. Allow the solution of sodium thiosulphate to flow slowly into the flask until the yellow color of the liquid has almost disappeared. Add a few drops of the starch paste, and with constant shaking continue to add the sodium thiosulphate solution until the blue color just disappears.

2. *Weighing the sample.* — Weigh about 0.125 gram of oil[1] on a small watch crystal or by other suitable means. The oil is first melted, mixed thoroughly, poured onto the crystal, and allowed to cool. Introduce the watch crystal into a wide-mouth 16-ounce bottle with ground-glass stopper.

3. *Absorption of iodine.* — The oil in the bottle is dissolved in 10 c.c. of chloroform. After complete solution has taken place, 25 c.c. of the iodine solution are added. Allow to stand, with occasional shaking, for 30 minutes. The excess of iodine should be at least 60 per cent of the amount added.

4. *Titration of the unabsorbed iodine.* — Add 10 c.c. of the potassium iodide solution and shake thoroughly, then add 100 c.c. of distilled water to the contents of the bottle. Titrate the excess of iodine with the sodium thiosulphate solution, which is added gradually, with constant shaking, until the yellow color of the solution has almost disappeared. Add a few drops of starch paste, and continue the titration until the blue color has entirely disappeared. Toward the end of the reaction stopper the bottle and shake

[1] If ordinary fats of low absorbing power are being tested, the sample may weigh as much as one-half gram. Usual oils should be taken in samples of from 0.150 to 0.250 grams.

violently, so that any iodine remaining in solution in the chloroform may be taken up by the potassium iodide solution.

5. *Setting the value of iodine solution by thiosulphate solution.* — At the time of adding the iodine solution to the oil, two bottles of the same size as those used for the determination should be employed for conducting the operation described above, but without the presence of any oil. In every other respect the performance of the blank experiments should be just as described. These blank experiments must be made each time the iodine solution is used. Great care must be taken that the temperature of the solution does not change during the time of the operation, as acetic acid has a very high coefficient of expansion, and a slight change of temperature makes an appreciable difference in the strength of the solution. Example blank determinations: (1) Forty c.c. iodine solution required 62.05 c.c. of sodium thiosulphate solution. (2) Forty c.c. iodine solution required 62.15 c.c. of sodium thiosulphate solution. Mean, 62.1 c.c.

Per cent of iodine absorbed:

Weight of oil taken	grams..	1.0479
Quantity of iodine solution used	cubic centimeters..	40.0
Thiosulphate equivalent to iodine used	do....	62.1
Thiosulphate equivalent to remaining iodine	do....	30.2
Thiosulphate equivalent to iodine absorbed	do....	31.9
Per cent of iodine absorbed ($31.9 \times 0.012 \times 100 \div 1.0479$)		39.61

The following precautions should be exercised in the use of this solution:

1. Great care must be used to prevent change of temperature of the solution, and where any number of determinations are to be made, blanks should be measured out at short intervals. (This precaution applies as well to the use of the Hübl solution, as the coefficient of expansion of alcohol is large.)

2. When the potassium iodide is added the solution should be thoroughly mixed before the addition of water.

3. The acetic acid must be full strength and pure in order to obtain a solution which will keep well.

Determination of Iodine Absorption — Wijs Method.[1]

Dissolve 13.2 grams iodine in acetic acid, same as used in Hanus solution, and run in current of dried and purified chlorine gas until the halogen content is nearly doubled; a slight excess of iodine should be allowed. The solution may also be made by dissolving 10 grams iodine trichloride in glacial acetic acid and adding 10.8 grams of iodine.

The solution is used in the same manner as in the Hanus method except that an excess of 70 per cent of the iodine added is allowed; 10 c.c. of the potassium iodide solution is added, and the time of reaction is made 15 minutes to 30 minutes, depending on whether a nondrying oil, a drying oil, or a fat is tested. After the potassium iodide solution is added the mixture must be shaken thoroughly before adding the water.

An improved method of determining the presence of rosin arises from either of these methods for iodine absorption, being based on the low constant and the red coloration produced by either rosin or rosin oil.

[1] The original sources of these improved methods are given in the bulletin referred to as follows: Hanus, *Zeits. Nahr. Genussm.*, 1901, 4, 913; *J. Soc. Chem. Ind.*, 1902, 455: Wijs, *Berichte*, 1898, 752; *J. Soc. Chem. Ind., loc. cit.*

When oils are mixed with concentrated sulphuric acid a rise of temperature occurs. Under standard conditions this increase of temperature is constant for a given oil. The number of degrees centigrade of rise of temperature of 50 grams of oil with 10 c.c. of concentrated acid is the Maumené number. Olsen[1] summarizes the results of various experiments as follows:

Niger oil	81 to 82	Almond oil	51 to 54
Crude cotton-seed oil	61 to 84	Peanut oil	45.5 to 67
Refined cotton-seed oil	74 to 77	Olive oil	32 to 45
Sesame oil	63 to 68	Castor oil	46 to 47
Colza oil	51 to 64		

Raw linseed oil, 100 to 110.

Maumené Test.

A 1½-inch 7-ounce heat-resisting glass foot tube is counterbalanced and exactly 50 grams of the oil are introduced. A bottle of c. p. sulphuric acid is prepared, sp. gr. 1.845. A thermometer should be placed inside this bottle, which should be well stoppered. The acid bottle and oil tube are placed in water in a tin vessel and heated to a temperature of 27 degrees C. Then 10 c.c. of the acid are drawn out with a pipette and dropped very slowly into the oil, without touching the sides, while stirring with the thermometer. The acid should be dropped in not faster than at the rate of 1 c.c. every 5 seconds. After mixing, the stirring should continue for 30 seconds, and the maximum rise of temperature noted. This test should be made only by a skilled chemist.

The errors in the usual Maumené determination, arising from the transmission of heat and the varying strength of the acid are avoided in the specific temperature test. In this, 50 c.c. of pure water are substituted for the oil, and the rise of temperature noted. Dividing the Maumené number by this rise in temperature with water, and multiplying by 100, we have the *specific temperature number*, by which oils may be compared without the same amount of dependence upon uncertain conditions of heat insulation and acid strength. Dr. Olsen recommends the use of an insulation of asbestos and plaster of Paris about the oil beaker as preferable to submergence in water.

The Maumené number and iodine absorption number are of especial importance in the examination of linseed oil because that oil gives results entirely different from those obtained with other oils. Minor chemical tests, infrequently made, are the following: determination of the acid value,[2] the ether value (difference between the saponification and acid values), the Reichert value (number of cubic centimeters of $\frac{N}{10}$ potash

[1] *Op. cit.*, p. 419.

[2] Oxidation increases the percentage of free acids in oil.

required to neutralize the acid from 2.5 grams of oil contained in 100 c.c. of distillate passing off at the rate of 110 c.c. in one-half hour), the Reichert-Meissl value (obtained like the Reichert, but with 5 grams of oil), the Hehner value (percentage of insoluble acids; determinable also by the Hanus method), the acetyl value, based on the amount of acetic acid liberated by the acetylated fatty acid produced by the action of acetic anhydride upon the oil, and the hexobromide test, given by Lewkowitsch—one of increasing importance. As a feature of complete physical examination, the melting point of the fatty acids is sometimes determined. Detailed methods for making the above tests are given by Olsen, who also summarizes the results obtained on samples of various oils as follows:

Name of Oil.	Acetyl Value.	Specific Temperature Number.
Olive oil	4.7	89 to 102.7
Rape oil	6.3	125 to 152.5
Almond oil	5.8	117.6
Cotton-seed oil	16.6	163 to 192.4
Cod-liver oil	41.1 to 50.6	....
Cocoa butter	....	....
Tallow	....	....
Peanut oil	3.4	105 to 137
Sesame oil	11.5	....
Castor oil	153.4 to 156	89
Whale oil	11.6 to 23.1	100
Grape-seed oil	144.5	....
Seal oil	33.0 to 33.9	....
Mustard oil	....	130.9 to 189.4
Sunflower oil	....	166.7
Corn oil	....	190.2
Raw linseed oil	**6.85 to 8.7**	**313 to 349**

The adulterants to be looked for in linseed oil are rosin oil, rosin, mineral oils, corn oil, cotton-seed oil, menhaden oil, turpentine (rarely), hemp or rape oil.

The cheapest and most frequently used adulterants are the petroleum oils. These are lighter in weight than linseed and consequently reduce the specific gravity. Rosin oil is, therefore, frequently added with them to increase the specific gravity. Fish or menhaden oils are sometimes used, the latter forming a constituent of various smokestack points. The worst of linseed oil substitutes are those consisting of solutions of rosin

in hydrocarbon oils, which are again mixed with tar oil and rosin oil. Such imitations dry without durability. Other substitutes are obtained by dissolving metallic resinates in tar oil or petroleum. Many substitutes are made with rosin oil, but they are apt to dry very slowly and remain sticky, and when used for painting will damage even a subsequent good coat, so that nothing but actual scraping off will remedy a coat of paint which proves defective as a result of the use of rosin oil. Oxidized rosin oil made by distilling the best rosin fractionally and blowing the middle distillation is a most dangerous adulterant. This process completely changes the nature of the rosin oil, making the color a pale brown or yellow, the smell pleasant, and increasing the viscosity. Such oil dries quickly, especially if mixed with boiled linseed oil. The cost of plant for its manufacture is heavy.

Linseed oil is sometimes accidentally adulterated with mustard oil. The presence of this material may be detected by allowing the oil to stand for a few days at a temperature of 50 degrees F., when a flaky yellow precipitate will appear.

An oil frequently used for adulteration of linseed is corn oil, which, however, possesses no drying properties and can only be used in small quantities with linseed. Corn oil and the cake are by-products from the manufacture of corn into glucose and grape sugar. The oil is reddish-yellow in color and pleasant in taste. It is used as an adulterant for linseed oil in the manufacture of paints, leather dressing, various kinds of soap and rubber substitutes. Corn oil cake, the residue after compressing the oil, is used as a feeding stuff, especially for dairy cattle. The extraction of the oil does not decrease the value of the corn germ, so that the oil is secured as a by-product at little cost beyond the expense of extraction. The corn cake is usually worth about $20 per ton, and the oil from three to four cents per pound. Only the germs of the corn kernel are used in oil extraction. They are ground, heated, and pressed the same as flaxseed. The solvent process of percolation has also been recently applied to the extraction of corn oil. The manufacture of corn oil is particularly adapted to a corn-products mill manufacturing hominy and other foods. The corn-oil mill utilizes the waste product of the corn-products mill. The corn-products mill utilizes the residue of the corn, after removing the germs, in the manufacture of starch, from which in turn is derived a great variety of products, such as dextrines, gums, glucose, and grape sugars. The demand for corn oil is steadily increasing.

Pure corn oil heated to 400 degrees F. bleaches, then breaks by forming bubbles which coagulate into reddish flakes upon the top of the tube. The smell is offensive at 400 degrees, but not upon ignition, when the oil burns quickly and freely.

Adulterated and substitute linseed oils are variously named, and the activity of the business depends largely upon the price of linseed, the trade in adulterated oils being naturally most brisk when linseed oil is high in price. Some of the substitute oils (or *superior* oils, as claimed by the makers in some instances) are the Boiled Java Oil, the Deodorized Corn Oil, the Usaperfect Drier Oil, Lucol Oil, Excelsior Oil, Cherry Paint Oil, etc., etc., etc. Nearly all of these are offered as competitors of pure linseed oil, and many of them are claimed to contain varying percentages of the last; all of which serves to establish the prestige of linseed as the commercial drying oil *par excellence.* The usefulness of the substitute oils is generally limited to the rougher kinds of outdoor painting. The only really competitive oils are poppy oil and walnut oil, both having superior drying qualities, but not being produced in commercial quantities, and China wood oil.

One of the worst forms of adulteration, now, however, rarely practiced, consisted in mixing inferior or damaged linseed oil with pure raw oil. Some years ago this was a common practice among traders, if not among crushers. One mixture consisted of 40 per cent of pure raw oil, 8 per cent of drier, and 52 per cent of screenings oil. The specific gravity of the product was .969, and the oil foamed heavily upon heating. The undiluted screenings oil has seldom found any market. It is opaque, greenish, and has a specific gravity of .942. A widely sold mixture contained 40 parts of raw and 60 parts of corn oil per 100. The absolute lack of drying quality soon drove it out of the market. Corn oil and screenings foots, boiled-oil foots, refined-oil foots, etc., have all formed the basis of mixtures, but the resulting product can be distinguished from genuine linseed oil at a glance. The only safe adulteration in this class is by means of a small proportion of corn oil; but the profit in such a mixture is too small for it to become general.

In many of the states statutes are in force relating to the matter of linseed oil adulteration. In New York, Article XV, Chapter 584, Laws of 1906,[1] provides that no person, firm or corporation shall manufacture or mix for sale, sell, or offer for sale, under the name of raw linseed oil, any

[1] As amended by Chapter 226 of the Laws of 1907, passed April 26, 1907.

article which is not wholly the product of commercially pure linseed or flaxseed. Nor shall any person, firm or corporation manufacture or mix for sale, sell, or offer for sale, under the name of boiled linseed oil, any article, unless the oil from which said article is made be wholly the product of commercially pure linseed or flaxseed, and unless the same has been heated to at least 225 degrees F. No person shall sell such adulterated linseed or flaxseed oil without notifying the purchaser that same is adulterated. The law is not to be construed as prohibiting the manufacture or sale of any such compound or imitation providing the container shall be plainly marked, and the purchaser notified, as aforesaid.

Violation of the act is a misdemeanor, punishable by a fine of from $50 to $500, or by imprisonment not exceeding one year, or by both. The enforcement of the act is charged to the commissioner of agriculture, who, with his agents, is empowered to enter places where linseed oil is stored or kept on sale and to open and sample from any package supposed to contain linseed oil. In addition to the penalty specified, there may be recovered a fixed penalty of $100 for each offense upon suit in the state courts in the name of the people by the commissioner of agriculture.

Under the linseed-oil law of Pennsylvania,[1] tests of 503 samples of linseed oil by Loomis, including 368 of raw and 135 of boiled, showed 11 cases of adulteration of raw oil and 15 of boiled oil. The specific gravity of the pure raw oils varied from .932 to .936 at 60 degrees F., that of the boiled oils from .932 to .945.

Linseed oil is sometimes impure as the result of the presence of injurious material in the seed, or of admixture of oil prepared from inferior seed. Such oils dry slowly and imperfectly, without hardness. They frequently have a greenish color,[2] which, however, may disappear in boiling. Chemical tests are usually inadequate to detect impurities of this class, the best criteria being the per cent of gain in weight and time required for drying.

China wood oil is rapidly becoming conspicuous as a linseed oil substitute in the varnish trade. During 1902 nearly $2,000,000 worth of it was shipped from Hankau, China. Previous to 1899 practically none of this oil was brought into the United States. There are two United

[1] January 25, 1901. Pennsylvania has been a pioneer state in pure-oil legislation.

[2] Baltic seed, however, even when perfectly pure, may give a greenish oil.

States firms in Hankau engaged in the export of China wood oil, one of which shipped 200,000 gallons as early as 1903. The consumption of the oil in the United States has been steadily increasing. There are two grades of the oil, one yellow and the other darker. Only the former is exported. The oil is brought to seaboard in bamboo baskets lined with oil paper, the baskets holding about one picul each. As much as one-third of the oil is sometimes lost in transportation. The most serious drawback to the trade in the oil is the difficulty in obtaining barrels, empty barrels being an expensive commodity to ship to China. The seed of the tung tree, which produces this oil, has been shipped to California for planting, and it is stated that the trees thus far are doing well. The oil is extremely poisonous and, as received from the Chinese, subject to heavy adulteration.

Each tree produces from 20 to 50 pounds of nuts, yielding about 40 per cent of oil. Attempts have been made to cultivate the tree in the botanical gardens of southern Europe, but unsuccessfully. The active producing provinces in China comprise the districts of Hunaw, Hupeh, and Szechuen. The trees thrive on stony ground. The oil has been studied by Claetz, Davies, Holmes, De Nigri, and others, but its properties are not yet thoroughly understood. It solidifies at a temperature of about zero Fahrenheit. The iodine value (Hübl method) is 160, the saponification value 194, the insoluble fatty acids 96.4 per cent, 5 per cent is unsaponifiable, the free fatty acids amount to 3.1 per cent. The melting point of the mixed fatty acids is 99 degrees F., their freezing point 35 degrees F., their iodine value 150.1. The crude oil dries with extreme rapidity, but with an opaque film, due to the presence of mucilaginous matter, which also causes the oil to become waxy at low temperatures, when organic compounds analogous to stearates settle out. It cannot be used in its raw state, but is always chemically treated. It may be "boiled" with lead or manganese dryers, with rosin or with resinates, to hasten oxidation, but must not be heated above 350 degrees F., at which temperature it suddenly thickens to an insoluble gelatine-like substance which cannot be softened again. It is nearly always used in a mixture with linseed oil. Its characteristic lard-like odor may be detected in solutions as weak as 10 per cent. This is found to be an objection to its use for varnishes. It does not dissolve in alcohol, and hence cannot be used for spirit varnishes or lacquers. In cheap oil varnishes it dries with a flat, frosty, crawling surface. Varnish makers claim that by the

use of wood oil a satisfactory varnish may be prepared from rosin; but the process of compounding is one of much delicacy, and few manufacturers have been successful with it. According to Holley, quantities of China wood oil as low as 5 per cent may be detected, in varnish, by the characteristic odor given off when sandpapering a freshly dried coat.

CHAPTER XVII.

BOILED OIL.

Definition.—Cost of production.—Action of metallic dryers.—Method of producing boiled oil.—Liability to adulteration.—Its consequences.—Commercial dryers.—Time of drying.—Cold boiled oil.—Manganese dryer.—Use in producing boiled oil.—Combined dryer.—Specifications for boiled oil.—The rosin test.—Saponification test.—Tests for raw oil applicable for boiled oil.—Kettle boiling.—A lead boiled oil.—Preparation of concentrated dryers.—Pale boiled oils.—Putties.

Boiled linseed oil is oil which has been so treated as to dry with increased rapidity. In ordinary practice, raw oil spread in a thin coat on a surface exposed to the weather dries in about one week; boiled oil, prepared usually by the addition of certain metallic salts or "dryers" to the raw oil, either with or without the application of heat, in less than one day.[1] Boiled oil is commonly sold at a price one cent per gallon higher than that of raw oil. So-called "boiled" oil is sometimes "manufactured" by pouring a quantity of concentrated dryer directly into the bunghole of the barrel of raw oil. Such boiled oil is of inferior quality, whether the dryer used be made from pure linseed oil or not. In most cases the "dryer" is a gum dissolved in some volatile solvent, producing an oil which "dries" by evaporation of the solvent. Such adulteration is readily detected by the "flash" test.

Few crushers know exactly what it costs them to produce boiled oil from raw, the principal uncertainty resting in the questions of shrinkage and steam. The expense is small, but even if it were greater than the premium obtained for the oil, boiled oil would still be produced. Raw oil is a staple, like wheat or corn, and few consumers care where they buy it; but boiled oil is a specialty, and a brand once adopted by a buyer as satisfactory is not easily displaced. The boiled-oil trade is, therefore, one which is especially desirable from the standpoint of the crusher.

[1] A good boiled oil should dry indoors, in eight hours; outdoors, in summer weather, the time of drying will ordinarily not exceed 18 hours. Occasionally, however, boiled oil will require 30 or 40 hours for complete oxidation, depending upon conditions of temperature and humidity.

The rapidity of drying of linseed oil is increased by, —

First: Chemical treatment to which it may have been subjected.
Second: The age of the oil.
Third: Conditions under which it has been stored.
Fourth: Its temperature.
Fifth: The presence or absence of sunlight.
Sixth: The addition of certain dryers.

There is some difference of opinion as to why the introduction of metallic dryers increases the rapidity of drying of linseed oil. According to Liebig, the increased rapidity is due to the removal of the mucilaginous elements in the oil. This is disproved by the fact that bleached and varnish oils (that is, raw oil from which the mucilaginous elements have been removed) dry more slowly rather than more rapidly, than raw oil. Chevreul claims that the metallic admixtures act as suppliers of oxygen, and that heating is not essential. With the second part of this statement there can be no dispute. If the first part were true, then those substances which contain the largest percentage of oxygen, or of available oxygen, would be the most effective dryers. This, however, is not found to be the case. In the manufacture of concentrated dryers from black oxide of manganese, the most desirable manganese to use is by no means that which tests highest in percentage of available oxygen. The correct explanation is probably that the metallic substances added act as carriers of oxygen from the air to the oil, giving it an initial oxidation and making a subsequent oxidation on complete atmospheric exposure more rapid. Nearly all of the substances commonly used as dryers have a high affinity for oxygen, forming quite readily more strongly oxidized compounds. Thus litharge, PbO, passes to the form of red lead, Pb_3O_4, at a moderate heat. It gives up its excess of oxygen to the oil, becoming itself reduced to PbO again; and this process may be indefinitely repeated until the oil has absorbed the desired amount of oxygen.

$$3\,PbO + O = Pb_3O_4.$$
$$Pb_3O_4 + \text{oil} = (\text{oil} + O) + 3\,PbO.$$

A combination of lead and manganese makes a better dryer than either material alone. A boiled oil from lead dryers contracts in oxidizing; one from manganese expands. The most economical proportions are reached when in the boiled oil manganese dioxide constitutes about .05

per cent, lead oxide (PbO) about .2 per cent. When either constituent is used alone, the time of drying is increased. It is possible that one of the materials is especially active in absorbing the oxygen from the air, while the other is of particular value in giving it up to the oil. An intermediate transfer of oxygen from lead to manganese, or *vice versa*, must then occur. A great many different metallic compounds, principally, however, those of lead and manganese, increase the drying action of oil. It has been demonstrated that all compounds which act as dryers, when in paste form, by contact with linseed oil, are materials soluble in linseed oil on heating, and react with it to a greater or less degree in the cold.

The usual method of producing boiled oil in this country is by the addition to raw oil of from four to eight per cent of concentrated liquid dryer, that is, a liquid solution of metallic salts. In practice, the boiling is performed by first thoroughly heating and agitating the raw oil to expel all moisture (freshly made oil, of course, requiring more time for this) and then adding the previously heated dryer very slowly, agitating sufficiently to thoroughly mix the dryer through the oil. One mode of agitation for expelling moisture is, after heating the raw oil in the tank to 250 degrees, to pump the hot oil from the bottom out and into the top. Atmospheric agitation is also permissible. Where there are no facilities for preheating the dryer, the best substitute is to feed it in very slowly and paddle it vigorously into the oil by hand. The heating is usually done by hot steam coils within the boiling tank, and the best location for these coils is around the sides of the tank and not closer than ten inches to the bottom. Boiling tanks are used having a capacity of as much as 10,000 gallons of oil at one boiling. The oil is maintained at a high heat for some time after the addition and thorough mixture of the dryer. The longer the temperature is maintained, the darker the oil becomes. The scum which forms on the surface, the residue left in the tank, and the scrapings from the filter cloths are disposed of separately, either by working through the press room or in some other manner. There is no perceptible shrinkage other than there would be in the raw oil after separation of the foots. Oil that has been tanked or stored for some time is best for boiling, as for other purposes. Such oil will have already begun to absorb oxygen; aged oil will often gain not more than 10 per cent in weight upon drying. Foots should never be present in oil intended for boiling. The widespread use of concentrated dryers has made adulteration possible and profitable. Few, if any, of the crushers

manufacture their own dryer, and the difficulties in the way of its manufacture from pure linseed oil, owing to the inferior properties of that oil as a solvent, are such that from the first the manufacture of concentrated dryers has been looked upon as a business wholly based on sophistication. Probably "nine-tenths of all the adulterated linseed oil sold is boiled oil."

As concentrated dryers are used in proportions of only from 5 to 8 per cent, an even considerable amount of the adulteration in the dryer could not noticeably affect the quality of the boiled oil. Complaints of adulteration are more apt to be due to the use of inferior raw oil, usually of oil that is not clear. Boiled oil is darker, and does not show impurities or suspended matter quite as readily as raw oil. The result is that oil which is a little short of perfection in one respect or another frequently finds its way to the boiled-oil tank.

The choice of a material for a dryer depends mainly upon questions of convenience and availability. Manganese dioxide was formerly most commonly used in this country. It must be dissolved by the direct heat of a fire, which practically commits its manufacture into dryer into other hands than those of the crusher, who permanently dismissed the dangerous and uncertain open kettles from his plant when he discontinued the manufacture of kettle-boiled oil. Red lead is often used. This also requires a high temperature for solution. It dries hard and brittle. Litharge dries with a highly elastic coat. The various manganese salts act in various ways. Combined lead and manganese dryers are commonly employed, the manganese starting the drying operation. Such dryers are prepared by adding oxides of lead and manganese to melted rosin, producing a resinate, adding linseed oil, and cooling with turpentine or benzine. Lime is sometimes added to increase the drying effect, but it results in a hard, brittle film. Zinc sulphate and lead sulphate are stated to be excellent dryers. Prussian blue is the dryer commonly used in the preparation of patent leathers. An improvement on this material is the dryer made from by-product Prussian blue treated with an alkali in the presence of calcium oxide and water. This gives a very elastic film of moderate hardness; too elastic, in fact, for some applications, Manganese resinate, mangano-lead resinate, manganese linoleate. mangano-lead linoleate, manganese chloride, manganese borate, lead acetate, lead borate, lead linoleate, lead resinate, manganese sulphate, manganese acetate, manganese oxalate, and some zinc salts comprise the principal drying agents used, other than those mentioned.

According to one writer, while raw linseed oil initially unoxidized gains in weight from 17 to 18 per cent during the 6 to 8 days it requires for drying, boiled oil, which dries in 24 hours or less, gains only 14 to 15 per cent in weight,[1] and, as is well known, usually produces a less durable surface, the linoxates formed from the dryer salts being more flaky and brittle than linoxyn, the oxide from linolein. By using pure resinates, the metallic admixture constituting the dryer may be reduced to a very small percentage of the boiled oil, with a consequently lessened formation of linoxates and less detriment to the wearing quality of the oil. For some applications, however, no resinate dryers are permissible, since the use of resins, even in small proportions, may result in the "livering" of paints.

The practice of English refiners is to use, instead of concentrated liquid dryers, solid gums, or powders made from gums, which are introduced directly into the oil at a comparatively low temperature. These are usually linoleates or resinates of lead or manganese. They produce exceptionally bright clear oils [2] without adding to the cost other than the inevitable expense of steam and labor. Their purity can be easily determined. They are used in very small proportions,— from one to three per cent, — and by their use the manufacturer knows exactly what he is getting, and does not have to depend on the varnish maker for his dryer. Under the conditions of present practice in this country, few crushers know anything about the composition of the dryers they use.

A good drying "boiled" oil may be produced without the application of any heat whatever, by the incorporation of a suitable proportion of soluble oxidizing salt. Such oils usually involve the preparation of a preliminary concentrated solution of resinates or linoleates in hot linseed oil and turpentine. In preparing boiled oil by heat, the dryer or dryer solution may be added when a temperature of about 250 degrees is reached, if a resinate dryer is used. Linoleate dryers require higher temperatures (320 degrees), and "straight" borates, hydrates, and oxides of manganese from 360 degrees upward. These latter temperatures cannot be obtained with steam boiling, and these latter chemicals are consequently little used. "Boiled" oil made without heat is extremely pale in color. The more dryer used, and the longer and hotter the oil

[1] Note the figures given by the Livache and Bishop test (page 225).

[2] These oils are much less apt to become cloudy in cold weather than our American boiled oils.

is heated, the darker the product. As American trade generally desires its boiled oil to have a dark red color, very little if any cold "boiled" oil is made. The resinate of manganese is used to the extent of about 2½ per cent of the weight of oil, the mangano-lead resinate in the same proportions, when applied direct in the boiling tank. The preliminary preparation of concentrated dryer is far more popular, and this is used in larger proportions. The cost of concentrated dryer varies with that of linseed oil, ordinarily ranging from 10 cents per gallon less to 10 cents per gallon more.

Formula for Manganese Dioxide Dryer.

For a batch of 350 gallons of dryer:

Heat 200 gallons of raw linseed oil to a temperature of 250 degrees, at which point add slowly 140 pounds of manganese dioxide, stirring the oil energetically while the manganese is being added. Foaming may be occasioned at this point, but it will very soon disappear.

Then add 150 gallons of raw oil. Heat the mixture gradually up to 525 degrees. The dryer should be maintained at 525 degrees for one hour prior to drawing the fire.

Eight hours is about the time required to complete one batch.

In making boiled oil from the concentrated dryer thus produced the following precautions are necessary:

First. — The raw oil should remain under heat until all signs of moisture are eliminated.

Second. — The dryer should be thoroughly warmed before it is introduced into the oil, say to a temperature of about 200 degrees F.

Third. — Dryer must be added after the raw oil has attained a temperature of not less then 250 degrees F. A higher temperature should be obtained if possible, although more than 275 degrees F. is unnecessary.

Fourth. — Agitate the oil while the dryer is being introduced and for not more than fifteen minutes thereafter, at which point the steam should be shut off. One of the objections to continuing the agitation of the oil unnecessarily is that it tends to lighten the color.

Fifth. — Five parts of manganese dioxide dryer to 95 parts of raw linseed oil is the proper combination to produce a satisfactory drying oil. Should this not produce a boiled oil dark enough for some markets, no harm can come from adding one to two per cent more of dryer, but in no event should the amount exceed seven parts of dryer to ninety-three parts of linseed oil. It is just as objectionable to have boiled oil oxidize too fast as too slow. To produce the best results, boiled oil should not dry in less than seven to eight hours under the most favorable drying conditions.

One of the most commonly used concentrated dryers is practically rosin oil, with lead and manganese salts. The pyroligneous acid from the rosin is removed by distillation under vacuum. A more elaborate concentrated dryer, producing a high-grade boiled oil, is made as follows:

Dissolve 10 parts of caustic soda in a maximum of 80 parts of water, with the aid of a steam jet. Call this solution A.

Take 20 parts of gum dammar, to which add 40 parts of linseed oil. Call this solution B.

To solution A add 64 parts of linseed oil. Make a solution of lead nitrate in water, using 3½ parts of nitrate. Weigh out 25 parts of manganese chloride. Remove the steam connection from the caustic soda solution A and while constantly stirring add first the lead nitrate and then the manganese chloride. Stir until saponification is complete. Allow the soap thus formed to drain as nearly dry as possible and set aside for 24 hours.

To the mixture of dammar and linseed oil, described as solution B, kept at a moderate heat over an open fire, add twice the quantity of soda oil soap made according to the above formula. Heat gradually and carefully to a maximum of 470 degrees; then add 7 parts of brown sugar of lead and 32 parts of linseed oil and draw the kettle off the fire. While hot, add 400 parts of oil, stirring constantly. Pump the dryer out from the top of the kettle so as not to get any sludge.

Rosin is sometimes used for making this dryer, instead of dammar. China wood oil is sometimes partially substituted for linseed oil. The boiled oil produced is sold at a good price. It is somewhat darker and less brilliant than the usual domestic boiled oils, but the drying qualities are good. In its preparation, 8000 gallons of raw oil are placed in a tank with 480 gallons of the concentrated dryer and heated to 230 degrees F. After agitation by blowing, the product is ready for filtration.

The various railroads and other large buyers have evolved standard specifications for boiled linseed oil, the Pennsylvania Railroad Company, for instance, requiring that it shall be free from admixture with any other oil, that it shall not flash below 500 degrees F., and shall not contain more than 2 per cent of material that is volatile. The Atchison, Topeka & Santa Fe Railroad Company issue the following specifications:

"The material desired is such as has been made from a pure raw linseed oil answering to approved specifications for the same, by boiling in an open kettle,[1] with the addition of lead and manganese dryers only. Oil will not be accepted which, first, has a specific gravity less than .939 or greater than .946; second, shows a rise with sulphuric acid of less than 100 or more than 110 degrees C. (Maumené test); third, flashes below 500 degrees F.; fourth, loses more than one-half of one per cent when heated three hours at 212 degrees F.; fifth, has more than 1½ per cent unsaponifiable; sixth, contains anything but lead and manganese dryers in solution; and seventh, has any suspended matter. In addition to the above there will be made any standard chemical test to determine quality or purity."

The permissible range of specific gravity for boiled oils differs with various authorities. A fairer range than the above stated is from .932 to .950. The United States Navy Department (1905) specifies a range of .934 to .940 at 70 degrees F. The specifications call for a "kettle boiled" oil. The other constants are also variously stated. The lead-

[1] Practically no boiled oil is thus manufactured.

ing tests for purity of boiled oil are, first, determination of the specific gravity; second, the flash test, which should be not below 500 degrees F.; and third, the determination of the igniting point, which should be above 600 degrees F. In addition to these, there is the test by drying, as follows: A weighed quantity of the oil is mixed with a large excess of some entirely inert substance like silica and then weighed from time to time. A good quality of raw oil, if fresh, gains from 16 to 17½ per cent in weight in drying; boiled oil from old tanked oil gains from 10 to 12 per cent; ordinary boiled oil from 15 to 17 per cent; an oil containing benzine or turpentine will show a decided loss during the first few hours, and many cheap compounded oils show an ultimate loss in weight instead of a gain. (See "Silica Drying Test, page 225.)

The Liebermann-Storch[1] test for the presence of rosin or rosin oil[2] is as follows:

"Two drops of the suspected oil are placed in a dry test tube, say five-eighths or three-fourths inch in diameter, one inch of acetic anhydride being run in on top. The whole is boiled or placed for a couple of minutes in boiling water until the oil dissolves. Next the tube and contents are cooled to the room temperature. With linseed oil the solution will cloud in cooling. To this is added a single drop of concentrated sulphuric acid; in the presence of rosin, rosin oil, or a resinate dryer there develops at once a purple red permanganate color, quickly changing to a brownish red. This reaction is very characteristic of rosin. An old fatty sample of boiled oil may give a reddish brown that masks this reaction, but never a purple."

"*Saponification Test.* — If an approximately 25 per cent solution of caustic soda be made by dissolving two ounces of 76 per cent caustic soda in 8 ounces of water, and we then take 2 ounces of this solution, one ounce of linseed oil, and one ounce of grain alcohol in a clean 8-ounce bottle and place this in a dish of water, and keep the water boiling for half an hour, and then fill our 8-ounce bottle with hot water and shake well, we will have a clear soap solution. On the other hand, doing the same with an oil containing petroleum or rosin oil, we find that the caustic alkali is without action upon it and we have a line of mineral oil on top of the soap. A word of caution with regard to this test would be that unless carefully carried out and sufficient alkali used even pure linseed oil may not be all saponified."

Other tests than the above which are useful are fractional distillation in order to determine benzine, turpentine, etc., the determination of bromine and iodine absorption and the percentage of free fatty acids.

[1] "The Liebermann-Storch reaction for rosin and rosin oil is one of the simplest and most satisfactory tests of its kind ever devised and frequently forms a ready means of determining the presence of rosin oil or a rosin dryer in boiled oil, but the results of this test must be verified by others and accepted with due caution, for some old samples of pure boiled oil will give a similar coloration."

[2] A better indication of the presence of rosin is given by the Hanus or Wijs test (page 229.)

The saponification figure for boiled oil is very nearly the same as that for raw, as are also the acid figure and the iodine absorption.

The nitric and other acid tests are not to be recommended, as the results are apt to be misleading. It is far easier to recognize fish oil by the smell when heated than by any acid test. The details of tests usually regarded as standard are given in Chapter XVI. Color reactions are of course modified by the changed color of the boiled oil, from those experienced with raw oil. In general, comparing boiled with raw oil, the former is darker in color, more viscous, heavier in gravity, and higher in acetyl value. The unsaponifiable matter and the volatile matter may both be slightly higher. The probable adulterations are the same as those of raw oil, mineral and rosin oils being most largely used.

There is very little boiled oil now made in this country over an open fire,[1] and it is questionable whether the claimed advantages of a kettle-boiled oil are tangible enough to make such boiled oil advisable. The operation was necessarily hazardous, and the often-mentioned advantages of "old-fashioned kettle-boiled oil" largely mythical. The oil was usually over-oxidized, drying quickly but wearing out rapidly.

One of the best known of the "kettle-boiled" oils was made over direct fire according to the following formula:

1500 gallons raw linseed oil,
80 pounds red lead,
80 pounds litharge.

The oil is first heated to a temperature of 460 degrees and the fire then drawn, — the temperature subsequently rising to about 500 degrees. It is then permitted to cool and pumped over into tanks. The usual procedure is for the watchman to start the fire under the kettle at about 4 A.M. When the temperature has ascended to 225 degrees, the other ingredients are gradually put in. The fire can be drawn usually about 2 P.M. It then requires about 16 hours to cool. The kettle must be cleaned out after making each batch. It is readily seen that the capacity of a single kettle under the best circumstances is not over 2½ batches per week. The cost is about as follows:

Per batch of 1500 gallons:

Coal, one-third ton	$ 1.25
Shrinkage — one barrel	25.00
Red lead	6.40
Litharge	6.40
Labor	6.00
Total	$47.05

[1] When so prepared, the oil is almost invariably produced from a concentrated dryer, and not by direct incorporation of drying ingredients.

or say three cents per gallon. An equally satisfactory oil is now produced from a concentrated dryer in precisely the same manner as ordinary boiled oil, the concentrated dryer being manufactured at a price less than that of ordinary linseed oil. The boiled oil dries slowly, but forms a powerful skin.

A kettle-boiled oil prepared from concentrated dryer was made as follows:[1]

Eighty gallons of raw oil are placed in the dryer kettle and gradually heated. When the first effervescence subsides, the following ingredients are slowly added: 20 pounds of manganese dioxide, 4 pounds of red lead, and 2 pounds of zinc sulphate. This is boiled for 3½ to 4 hours, meanwhile being constantly agitated. The fire is then drawn and the solution drawn off. To the sludge in the bottom of the kettle 80 gallons of raw oil are added, a new fire built, and at the same stage as before 10 pounds of manganese dioxide, 2 pounds of red lead, and 1 pound of zinc sulphate are added. The two solutions form concentrated dryer sufficient for the boiling of from 1200 to 1500 gallons of oil. The oil is placed in the boiling kettle, slowly heated, and when the temperature rises above 110 degrees the dryer is gradually introduced. The mixture should be agitated continually. The heating is continued for about 5 hours, after which the fire is drawn and about 10 pounds of red lead added.

Another concentrated dryer prepared for kettle-boiling contained 24 gallons raw oil, 30 pounds manganese dioxide, 5 pounds sugar of lead, 3 pounds borax, and 2 pounds zinc sulphate. Livache quotes, per 10 gallons of oil, the following quantities of drying substances as necessary to produce boiled oil at a single operation:

1. 2¼ pounds red lead and 2¼ pounds litharge,
2. 2¼ pounds litharge and 2¼ pounds sugar of lead,
3. 1⅛ pounds of red lead and 3⅜ pounds sugar of lead,
4. 1⅛ pounds to 3⅜ pounds of borate of manganese,
5. 2¼ pounds of hydrated oxide of manganese.

"Pale boiled" oils are sometimes called for, usually for export to the West Indies. They resemble ordinary boiled oils, excepting that the color is lighter, more like that of raw oil. Special ingredients are employed in the dryers used to avoid the usual darkening of color. A low temperature in boiling is also desirable.

Putty is a familiar product of linseed oil. Its usual composition is eighty-five parts of whiting and fifteen parts of raw oil. Bolted American Paris white is commonly used; sometimes imported whiting may be employed. For a quicker drying putty, boiled linseed oil should replace raw, and about ten per cent of dry white lead may be incorporated with

[1] John Bannon: *The Manufacture of Linseed Oil.* Chicago, 1897.

the whiting. Putty is largely adulterated, crude cotton-seed oil mixed with boiled linseed oil being used instead of the raw oil. By using a sufficient quantity of boiled oil, the inferior drying properties of the cotton-seed oil may be concealed; but the product is less durable than a pure putty. Common whiting adulterated with fine marble dust may further cheapen the product.

CHAPTER XVIII.

REFINED AND SPECIAL OILS.

Definition of refining.—Cold-pressed oil.—Calcutta oil.—Bleached and varnish oils.—Theory of bleaching.—Sunlight.—Physical and chemical constants of bleached oil.—Bleaching agents.—Operation of bleaching.—Fuller's earth.—Formulas.—Preparation of acid-bleached oils.—Oil for varnish making.—Manufacture of dark varnish oil.—Calcutta varnish oil.—A bleaching varnish oil.—A cheap light varnish oil.—A high-grade light varnish oil.—Price mechanical process oil.—Necessary equipment.—Thickening of oils.—Artificially aged oils.—Their properties.—Printer's inks.—Lithographer's oils.—Linoleum.—Rubber substitute.—Cost of boiling and refining.—Premium obtained for special oils.—Manufacture of soap.—Linseed-oil soap.—Deglycerization.—Its effect upon profit.—Method of conducting process.

Refined linseed oil is oil which has undergone chemical or mechanical treatment to fit it more perfectly for certain specified applications. When oil is to be used by paint grinders for mixing with light-colored pigments, it must be bleached in order that it may not darken the paint. When oil is to be used by varnish makers, it may or may not require bleaching, according to the color of varnish to be prepared; but it must have its "breaking" property removed.

Cold-pressed raw oil is the ideal varnish oil. As received from the presses, it does not break; and it may be bleached nearly water-white by the application of heat alone. Only its excessive cost prevents it from becoming the universal constituent of pure oil varnishes. Oil from Calcutta seed is highly prized in some quarters, particularly after having undergone the usual treatment for the destruction of the "breaking" tendency. Few consumers use Calcutta oil in its raw state. Neither as raw nor as varnish oil can the product from Calcutta seed be certainly distinguished from the American oil. Its demand is due partly to the prejudices of old-time varnish makers, who learned to use it when Calcutta seed furnished the bulk of the supply to Eastern oil mills, and when Western seed received in the East was always very impure; and to an even greater extent to the fact that Calcutta oil is produced by the crusher at intervals only of from two to five years. We know that old oil

gradually clarifies and eventually ceases to break. Practically all Calcutta oil is old oil, and to this fact, with that of the careful treatment given in preparation, are due its fine qualities. It commands a good price at all times, and the crusher can well afford to give it special consideration in the way of thorough filtration, careful refining, and good clean packages.

Boiled oil, although coming within the scope of the definition above given, is classed by itself and not as a refined oil. Another distinction commonly made is to speak exclusively of bleached oil as refined oil, regarding varnish oils as a separate class, whether bleached or not. We shall, however, include in the class of refined oils all treated linseed oil excepting boiled. This corresponds with the usual classification adopted in the accounting departments.

A bleached oil is one that has had its color lightened by any appropriate bleaching agent. It usually does not break; but in spite of this fact many bleached oils are unfit for use as varnish oils because of the presence of free acids or other ingredients which would injure varnishes. There are a few oils, however, which are marketed both as bleached and as light varnish oils. We will consider them under the latter heading. Bleaching, according to Dr. Toch, consists not in the removal of the dark coloring matter (chlorophyll), but in its change to a pale yellow coloring substance, xanthrophyll, by the influence of acid; for example, when sulphuric acid is slowly added to oil which is under agitation, preferably by air, the oil becomes cloudy and develops black clots, which may be filtered out, leaving the oil much paler than before. Chromic acid may also be used, as have been peroxide of hydrogen and the peroxides of calcium, magnesium, and zinc. These peroxides are made into a paste with water, one pound of paste sufficing to bleach 200 gallons of oil. During agitation of the mixture a strong solution of sulphuric acid is added.

Oil may be bleached by the action of sunlight alone; and oil so prepared is far superior to any chemically prepared oil. A thin film of oil in direct sunlight bleaches in two hours. On a commercial scale bleaching by sunlight requires about two weeks. It is practiced to some extent abroad, but in this country, where capital charges are higher, no oil is bleached in this manner. Ozone has been used as a bleaching agent, as has also the electric current, but neither on any large scale. Exposure to the air also partially bleaches oil. Chemically bleached oil does not wear as well as raw oil; any admixture whatever of foreign matter seems to have a detrimental effect upon the characteristic properties of linseed

oil. Some paint grinders, therefore, use raw oil, even in grinding white pigments, claiming that the resulting paint, after a few days' exposure, is just as white as one prepared from bleached oil, and that its wearing qualities are much better.

The physical constants of bleached oil are generally nearly the same as those of raw, its specific gravity being .93 to .94, its iodine number 170 to 180, and its saponification value 192. The various chemical tests given for raw oil must be applied to bleached oil with much caution, owing to the modification of results produced by the reagents resulting from the bleaching operation. Most bleached oils, as indeed nearly all special or refined oils, are purchased direct from the crusher; and as he depends upon these for his best market, they are prepared with special care and probably never adulterated. Complaints regarding bleached oils occur, if at all, as the result of accidental defects or misapplication.

Acid-bleached oils do not break, because the acid attacks and chars the elements which would otherwise separate upon heating and permits of their removal by filtration. An oil bleached by sodium peroxide, unless subjected to supplementary treatment, will break, and is consequently entirely unfit for varnish making. An acid-bleached oil may be used for varnishes if mixed with a basic dryer which will combine with the free acid; but the process involves too much risk to the product to be commonly practiced. Chloride of zinc, calcined magnesia, steam, hot air, tannin, salts of iron or alumina, lye, and sulphate of manganese have been variously recommended as refining agents; some producing primarily a bleaching effect, others a breaking of the oil at low temperature. Bleaching agents proper are, besides those already mentioned, the permanganate and bichromate of potash, linoleate of manganese, nitric acid, caustic soda, carbonate of potash, ferrous sulphate, basic lead acetate, lead sulphate, and various complex mixtures. Chlorine gas is probably the most effective and rapid of all bleachers, but can be separated from the product only with great difficulty. According to Lewkowitsch, oil made by extraction is unfit for use in paint grinding; and it is undeniable that very little percolated oil is sold for this purpose. Bleached oil dries, like raw, too slowly for its most popular use in painting. It is customary for the paint grinder to mix appropriate liquid dryers as required.

A good bleached oil must be yellowish white or yellow; the nearer to water-white, the more attractive the oil is to the average buyer, although such extreme decoloration is invariably obtained at the expense of the

drying or wearing qualities of the oil. A greenish hue is wholly undesirable. Lead-lined tanks of wood, usually square in shape, are commonly used for the bleaching process, these containing steam coils around the sides. Exhaust steam may be used for the initial heating, with live steam to supplement it. Agitation is produced, usually, by the introduction of air under pressure from submerged perforated pipes. The air divides the solution more finely and agitates it more thoroughly than any form of mechanical agitation. Besides this, it partially oxidizes the oil, thickening it and increasing its drying properties.

Fuller's earth is probably the most generally used bleaching agent in this country. This contains usually, in parts per 100, silica 65, alumina 20, iron 9, lime 6.[1] A small percentage of the earth is mixed with the oil, agitated for 3 or 4 hours, and the product slowly filtered. The temperature during agitation is maintained at about 200 degrees. The use of fuller's earth has the disadvantage of frequently imparting a greenish tinge to the oil, besides resulting in excessive shrinkage, or loss of oil, which is carried away in the sludge. Cases have been known where this sludge was fed, like ordinary foots, through the crushing mill, the earth itself thus eventually reaching the market as oil cake.

The ocher process of bleaching, once widely heralded, had the sole disadvantage of excessive cost. The ocher was prepared by removing all uncombined moisture by the application of heat, then dried and pulverized, and used in proportions of from one-twelfth to one-fourth of the amount of oil to be bleached. The mixture was agitated for forty minutes, then filtered. From 4 to 12 per cent of the oil was carried away in the sludge on the filter cloths. The oil was practically water-white.

One of the simplest formulas for a plain acid-bleached oil is as follows:

Agitate in a lead-lined tank 2800 gallons of raw oil. Add very slowly 28½ gallons of sulphuric acid at 66 degrees Bé. After all the acid has been added, run in 1550 gallons of a concentrated solution of cold salt water. Agitate for three hours. Allow to settle, then steam for six hours. Again settle, draw off the water, and filter. If the oil is desired especially light in color, it may be pumped to shallow tanks immediately under a glass roof, and exposed to bright sunlight for at least one week. Then filter by gravity only.

A simple bleached oil by the fuller's-earth process is thus prepared:

Treat raw oil at 165 degrees with 10 per cent of fuller's earth, with agitation and subsequent filtration. Dissolve the cloth sludge in naphtha and percolate by the "new process."

[1] The chemical composition is no indication of the value as a bleaching agent.

The following formula produces an excellent grinder's oil, also success fully used for the manufacture of printing inks, a supplementary "body ing" being required for the latter application. It is extremely low i specific gravity, pale and clear in color, but darkens upon continued heat It is sold at an advance of three cents per gallon over the price of oil, an can be profitably manufactured at that price.

To fifty parts of raw oil there are added in lead-lined tanks 2½ parts of sulphuric aci (66 degrees Bé.). The mixture is agitated by air for 10 hours, and 8 parts of water a added. The mixture is steamed until it boils, then allowed to settle for 36 hours. Th water is run off through a reclaiming tank, and the oil pumped to the filters. A shrink age of about 1⅓ per cent is experienced.

Varnish oils, properly so called, i.e., oils which will not break by an application of heat, are divided into the classes of "light" and "dark, the former being used for the higher grade, very light "spar" varnishes and the latter for other applications. An oil varnish consists of resin dissolved in linseed oil at high temperature, the solution being afterwar thinned with a volatile solvent. Gums or resins dissolve much mor readily in the volatile solvents, but such a solution forms a spirit varnish which dries with a brittle skin and is unsuitable for good work. An o varnish gives a more elastic and durable coat. Owing to the high tem peratures used in varnish preparation, the varnish oil must have it breaking property entirely eliminated; but on account of the expensiv and elaborate applications of oil varnishes the oil must retain its dura bility and elasticity unimpaired by the treatment given to prevent break ing. This in its simplest terms is the problem of varnish-oil preparation It is also of extreme importance, from the varnish maker's standpoin that the oil should undergo the application of heat quietly, without crack ling or foaming, like raw oil. This is largely a question of thoroughl removing the moisture. The question of rapidity of drying does no affect the problem, since the varnish makers incorporate their own dryer An aged raw oil would be entirely suitable as a dark varnish oil, bu storage is more expensive than chemical treatment. For the same reason light varnish oils are not produced, in this country at least, by the expo sure of such aged oils to sunlight. There remain only the standar methods of chemical or mechanical treatment, involving in all cases th removing of the "breaking" property by chemical treatment and, wit oils for light varnishes, an additional bleaching treatment.

A good dark varnish oil may be prepared by introducing one part of

30-degree solution of caustic soda in 160 parts of raw oil, agitating by air for 10 hours, and continuing the agitation until a sample of the oil may be heated up to the igniting point without breaking or foaming. Agitation with stirrer bars instead of air appears to produce a more brilliant oil, which bleaches to a lighter shade when heated. The specific gravity of this oil at 60 degrees F. is about .940 — an extremely high figure. Its property of bleaching when heated makes it suitable for many light varnishes, as well as for the darker shades; but this fact does not appear to be generally known. The shrinkage in making the oil is about four-tenths of one per cent. Dark varnish oils of this class are usually sold at a price one cent in advance of that of raw. Calcutta varnish oil, however, prepared by the same process is sold at the same price as Calcutta raw. The Calcutta varnish oil is sold to various varnish and patent-leather manufacturers. Its color is slightly greenish, and after heating it becomes a very pale green. It is low in specific gravity for a varnish oil — about .937.

A dark varnish oil which bleaches very notably under heat may be prepared by introducing a solution of 35 pounds of sulphuric acid (66 degrees Bé) in 60 pounds of water in 1250 gallons of oil. After agitating for 5 hours, a solution of 60 pounds of salt in 600 gallons of water is added slowly. Agitation for 5 hours and settling for 12 hours follow, after which the water is drained off and remaining moisture expelled by further agitation. The oil is not filtered until cold. It bleaches to a pale straw-green color under heat.

The market for dark varnish oils is quite limited, in spite of the fact that they bleach, at the ordinary temperature of the varnish kettle, to a color fully as light as that of the initially "light" varnish oils. Most crushers, however, are obliged to produce the latter; and a refining department is usually judged by its ability to produce a fancy light oil for the varnish trade which will readily command a price from 2 to 3 cents per gallon higher than that of raw oil. One of the cheaper oils of this grade is made by preparing a solution of 6½ parts of caustic soda, 10 parts of salt, and 500 parts of water, which is run into 1250 gallons of oil while the mixture is thoroughly agitated. After heating for 5 hours and settling for 24 hours, the water is run off by way of a reclaiming tank, and the oil is ready for filtration as soon as cool. This oil is free from acid, on which account it is especially popular among some varnish makers. It bleaches lighter than any other varnish oil upon

continued heat, but is not light in shade as prepared. A better color could be imparted by giving it a fuller's-earth treatment, which, however, would add appreciably to the cost, ordinarily quite high. It is a somewhat difficult matter to get the oil "just right" with this process.

One of the best of the chemically prepared light varnish oils is made by mixing 4 parts of 10-degree caustic soda solution with 25 parts of oil, with agitation of the mixture somewhat cautiously conducted to avoid saponification. After settling 96 hours to precipitate the moisture, 2 per cent of 66-degree sulphuric acid is added to the oil in a solution made by adding 100 pounds of acid to 75 pounds of oil. Agitation should continue during the introduction of the acid, which must be effected gradually. After standing for 12 hours, the mixture is washed with a steam spray, again allowed to stand for 96 hours, and treated with 2 per cent of fuller's earth at a temperature of 215 degrees F. The shrinkage in making this oil is high. It commands a price 3 cents above that of raw oil. It bleaches to a light straw color at 550 degrees F., and is quite light in color even at 60 degrees. It is extremely high in specific gravity, and is used for the highest-grade varnishes.

All of these fancy varnish oils are produced by chemical treatment, necessarily involving disadvantageous features. We now describe an oil produced by mechanical means alone, which is, moreover, from the varnish maker's standpoint one of the best oils available for the production of all grades of varnish. This is the patented P. M. P. (Price Mechanical Process) oil, almost invariably made from new-process oil. It is expensive to make and difficult to produce of uniform quality. It is very light in color, varying from straw to greenish, and sometimes assumes a more pronounced greenish tint upon heating.

The oil is first put in a superheating tank, where superheated steam at a temperature of 450 degrees is blown through it. This decomposes the "breakable" part of the oil, some of it passing off as powerful corrosive vapors and the balance settling in the tank when the steam is shut off. The oil is then drawn out of the tank and run through a centrifugal separator, which thoroughly removes the coagulated portion, leaving a clear and non-breakable oil. It is then given a very light treatment with fuller's earth, in order to lighten the color, and filtered. It is then refrigerated down to a temperature of 16 degrees F. below zero by pumping it through coils suspended in a brine tank, and then quickly filtered, so as to remove the stearine, etc., deposited by cold, before the oil is warmed up and reabsorbs this stearine. This is one of the most critical parts of the process, because if this stearine is not thoroughly removed the oil will show a light flocculent precipitate in very cold weather.

The capacity of the plant used is about 5000 gallons per day. It is quite difficult to estimate the exact cost of manufacture of the oil, owing to the fact that there have been no accurate data kept as to the percentage of shrinkage. The highest percentage claimed by one operator was between 3 per cent and 4 per cent. Even this high per cent might permit of the economical sale of the oil at its differential of 3 cents when oil was very cheap, but when oil is worth more than 50 cents it is questionable whether P. M. P. oil can be produced at a 3-cent price. There is considerable opportunity for economy in the details of the operation. The equipment consists of superheater, separator, brine pump, ammonia compressor, enameled-tile-lined heating tank, and brine tanks. The oil finds application for paint grinding as well as for the production of varnishes, but is too expensive to be in general demand for the former purpose.

Besides bleaching and breaking, linseed oil is frequently subjected to a third method of treatment, fitting it for some further special applications. From a non-breaking varnish oil, by continued heat, a thick, jelly-like substance is eventually formed, which is used as a constituent of patent leather and printer's inks. Ordinary raw oil may be concentrated in the same way, and if the "breakable" qualities are eliminated by agitation with air during the heating the resulting product is highly oxidized, ready to dry with especial quickness. This finds its application in the linoleum industry. An excessively concentrated product may be made so hard as to duplicate the properties of hard rubber. The "sweetmeats" formed by continued heating of a varnish oil are one of the tests of the quality of such an oil. They should form readily and uniformly when the oil is heated in the varnish kettle to a temperature of from 480 to 550 degrees, the weight having then decreased about 8 per cent. For printer's inks, the concentration is carried on until the loss of weight reaches about 16 per cent. A still further concentration of product results in the formation of an imitation "hard rubber."

A preliminary thickening of raw oil by heating and blowing, with a view to fit it for use for such further concentration, results in the production of various special artificially "aged" oils which find a wide market. They are even employed to some extent by paint grinders; but for this application must be pale in color. The process of blowing, if improperly conducted, may, however, actually reduce the drying power of the oil, it then becoming "fat" and unsuitable for any application.

These "aged" oils are produced by the combined influences of air and heat, the details of the process having been kept secret. They are blown at a high temperature, then allowed to cool off, and heated again. About three days are required to complete a batch. The kettles have double steam coils, and are jacketed. Two tanks are used together, pumping from one over into the other. The cost of manufacturing this oil is said to be negative, the gain in weight more than offsetting the expense of operation. The oil is used by patent-leather and linoleum manufacturers. It does not break, and bleaches under heat. There should be no foam when heating the oil. It can readily be distinguished from raw oil by its high specific gravity, this being .946 at 60 degrees F. It is also more viscous than raw oil.

Rape oil intended for lubrication is usually subjected to a similar blowing treatment.

Oils aged by blowing are more soluble in alcohol than raw oils, and according to Lewkowitsch the acetyl values are higher and the iodine absorption lower. The principal adulterants are rosin oil and resins. Analysis should be directed at their detection and toward the determination of unsaponifiable matter. According to Hall, the specific gravity and iodine number vary with the degree of concentration and are of little value in determining purity. The oil has a decided bloom, which should not be assumed to indicate, necessarily, the presence of mineral oil.

Concentrated blown oils are soluble in raw oil and in various volatile substances. After drying, they are practically insoluble. A mixture of raw oil and dryer, subjected to a rather more intense concentration than is practiced with ordinary "aged" oils, produces a very thick heavy product which foams heavily when subjected to high heat. It is used in coating wire mesh for metal windows and skylights, the netting being dipped into the oil several times. It dries with a very thick skin.

Printer's inks are made by grinding a suitable pigment into a varnish. The pigments may be black, white, or colored. For the cheaper inks, rosin oil varnishes are used. The rosin oil is prepared by destructive distillation of rosin in cast-iron stills, producing water, resinic acids, and a series of rosin oils. By repeated distillation of the oils the water and acids are removed and the oils purified. The high-grade inks are prepared by concentrating a non-breaking (varnish) linseed oil by continued heat until it becomes thick and viscous, and then grinding in the pigment. The various concentrated linseed oils are designated by numbers which indicate the effect of time, method, and temperature on the thickening. For more rapid drying various oxidizing agents may be added during concentration. The pigments used are carbon, mineral colors, coal-tar derivatives, or substances formed by precipitating water-soluble dyes on a suitable base. The grinding of pigment and oil is

accomplished in mills or mixers. The quality of the ink is judged from its consistency, strength, intensity of color, permanence, brilliancy, and drying and working qualities.

Lithographer's varnish should be clear, transparent, and only slightly darker than raw oil. It is prepared in the same way as the oil varnish for printer's inks, but usually without dryers. It sometimes has a faint reddish tint, and may exhibit a green fluorescence.

Linseed oil intended for linoleum manufacture is thoroughly oxidized until it forms a yellow gelatinous mass heavier than water and quite insoluble. It is mixed with rosin, cork fragments, and fillers, in the preparation of linoleum. The best linoleum is made from the most thoroughly oxidized oil. Extraction of the soluble oil with ether indicates the degree of perfectness of the oxidation. An average sample of linoleum analyzed by Pinette (quoted by Lewkowitsch) gave, parts in 100: water, 3.01; ether-soluble linseed oil, 10.60; cork, 73.63; ash, 12.76.

Vulcanized oils are prepared from "blown" oils by heating with sulphur or by treatment with sulphur chloride in the cold. They are used as substitutes for india-rubber, and have an iodine value ranging from 52.6 to 56.3, with an acetyl value from 19.6 to 21.0. (Lewkowitsch.) Raw oil may be vulcanized, but the consumption of sulphur chloride is excessive.

The cost of these special oils is largely that of steam and labor. The variations in the formulas used by different manufacturers affect the quality of the oil more noticeably than its cost. Shrinkage is a leading item in the expense of production. Accurate determinations of the cost of steam are impossible, but close approximations may be, and should be, made. Most crushers have a general account "Boiling and Refining" and do not attempt much subdivision. The special oils serve to establish a permanent market, and if they cost more to produce than the advanced price realized, the difference is regarded as an item of selling expense. In a few cases the shrinkage is credited to the raw-oil stock, but this cannot be said to be general practice; hence the records of cost of production of special oils are usually ridiculously low, particularly as no charge is made to "Boiling and Refining" account to represent the steam used. Special oils sell at from one to five cents advance over the price of raw oil. It is the aim of every crusher to produce special oils that will suit as many special markets as possible without being obliged to work with too many different

formulas. The following are the leading grades which every crusher should aim to produce:

Boiled, at 1 cent premium,
Bleached, at 2 cents premium,
Light varnish, at 3 cents premium;

and in addition to these a cheap dark varnish oil and a concentrated, blown, "aged" oil will often be found profitable.

Besides these common products of raw oil there is one other which is potentially of importance. Whenever the cost of linseed oil is low, so that it may compete with other oils, as an oil, irrespective of its drying qualities, its consumption vastly increases owing to the enormous demands from the soap industry. Any cheap fat is suitable for making soap. In Europe, the soft linseed-oil soap is most highly prized; and its use in this country is increasing more rapidly than the relatively high price of oil would indicate as possible. Linseed oil can be turned into soap at a cost of 1½ cents per pound, including (barrel) packages, less than half of a pound of oil producing a pound of soap. If oil is worth 37½ cents per gallon of 7½ pounds, or 5 cents per pound, the soap can be easily produced for 4 cents per pound, a competitive price. The main items of cost, in order of their importance, are oil, potash, barrels, and steam. The best location for a soap plant is at a good soap market, such as the large cities furnish. The best city to select would be one in which linseed oil could be produced cheaply, such as Buffalo or Cleveland.

The soap is soft, darker in color than linseed oil, and is used for washing floors, decks, wooden vessels, enameled ware, marbles and statuary, woolens, etc. Its special application, however, is to varnished surfaces, such as the exterior of railway coaches. Another wide field for the soap is as a "cutting oil" in the machine shops, for lubricating and cooling taps, dies, drills, cutters, reamers, and lathe tools. A soap plant having a capacity of 10 barrels per 10-hour day can easily be installed complete for less than $1000. The preparation of the soap is as follows: raw oil, unfiltered, and rosin are mixed by heating. This mixture is saponified by the successive addition of solutions of caustic potash and pearlash in increasing strengths. After complete saponification, the soap, while hot, is run into barrels which hold about 450 pounds each.

In making soap, the glycerine, which is present as a glyceride of the fatty acids, does not combine with the alkali. By removing it the remaining fatty acids are suitable for use as soap stock, and the revenue derived from the glycerine, less the cost of manufacture and the shrinkage, is gain. In addition, it is claimed that some commercial advantage arises from the fact that the deglycerized oil can be made into soap by the use of carbonate of potash only, no caustic potash being required. The leading process of deglycerizing, controlled by Joslin Schmidt & Co. of Cincinnati, is claimed to produce from 100 pounds of linseed oil 10 pounds of actual dynamite glycerine (including the glycerine radical, C_3H_5, in the oil plus the hydroxyl) and about 94½ pounds of fatty acids, which fatty acids will make the same quantity of soap as 100 pounds of oil. The actual expense of the process for chemicals, steam, and labor is stated to be not over 25 cents for 100 pounds of oil treated. The cost figures are therefore as follows:

100 pounds of oil treated costs at 6 cents	$6.00
Expense of treatment	.25
Total expense	$6.25
Yield 10 per cent of glycerine at 10 cents	$1.00
Ninety-five per cent of fatty acids at $5.52 equals	5.25
Total	$6.25

It will be seen, therefore, that the result of the treatment, from the oil standpoint, is to produce an oil which costs the manufacturer one-half cent per pound less than the original oil. If this fatty acid product costing three and three-fourths cents per gallon less than linseed oil could be applied to some useful purpose there would be a considerable profit in the process.

The fatty acids are darker than raw oil, have a more powerful odor, and should have a specific gravity lower than that of raw oil. When heated, they boil violently, emitting a very powerful smell, forming dense white vapors and darkening. They partially solidify upon exposure to a moderate degree of cold. They do not dry completely even under long exposure to the atmosphere. That portion of the acid which solidifies upon exposure to the cold can be removed by filtration. The acids are sometimes used as adulterants for linseed oil. The acids cannot be used alone in making soap, forming a lumpy, unworkable mass in the vat; but by mixing with a large per-

centage of linseed oil they are readily saponified. The reagent used in the process costs very little, and this cost is included in the estimate of 25 cents per 100 pounds for the treatment. A plant with a total capacity for deglycerizing 10,000 pounds of oil per day would cost less than $1000. A small experimental plant composed of empty cocoanut oil pipes with a capacity of about 1000 pounds per day could be set up for less than $100. The darker color resulting from the use of fatty acids rather than raw oil in making soap may be obviated by deglycerizing a bleached oil. The process of deglycerizing consists in simply boiling the fat in closely covered wooden tanks of appropriate size with water and a small percentage of the special chemical or saponifier which causes the separation of the glycerine. The boiling is done with steam and is very inexpensive, and at the end of one or two boils of varying duration (according to the kind of stock in hand and the purpose to which the resultant fatty acid is to be put) the glycerine is found to be present in the water which settles to the bottom, and the fatty acids are ready to be used at once for the production of soap. The glycerine water after treatment with a small percentage of common lime is ready to be evaporated in any kind of evaporating machinery.

The advantages of the "Twitchell" process are claimed to be the separation of chemically pure glycerine of high strength, the production of "sweet" fatty acids saponifiable by carbonates alone, simplicity, and low cost of operation. Failures in working the process are usually attributable to foul tanks, contact with iron, the use of hard or impure water or an improper quantity of water, failure to thoroughly purify the oil by the preliminary acid wash, the use of old or oxidized oil or too high a percentage of saponifier, or the exposure of the contents of the tank to oil.

CHAPTER XIX.

THE LINSEED OIL MARKET.

Not an article of direct consumption.—Basis for its applications.—Variations in price.—Linseed oil a staple.—Mixed paints.—Defects experienced.—Requisites of good painting.—Raw oil the best for painting.—Production of varnish.—Defects of varnish.—Lead grinding.—Linoleum.—Importance of special oil production.—Dealing in outside oils.—Transportation of linseed oil.—Price of oil related to freight on oil, seed, and cake.—Motor trucks for local shipment.—Complaints from linseed-oil customers.—Sale of linseed oil on commercial exchanges.

Raw linseed oil is practically never an article of direct consumption, although its ultimate applications are more varied than those of almost any other commodity. A large proportion of the raw oil produced by the crushers is boiled, refined, or otherwise treated at the mills to fit it for special markets. This treated oil is itself seldom directly consumed. Most of it is mixed with other substances to form well-known standard products, such as paints and varnishes, and others in which the identity of the linseed oil is apparently entirely lost. For example, comparatively few people know that the ink with which this book is printed and the covers in which it is bound are products of linseed oil and virtually impossible without linseed oil. Such raw oil as is marketed by the crusher is, in the vast majority of cases, subjected to further treatment by the purchaser before it is ultimately used. Linseed oil is to the general public, therefore, very much of an abstraction.

The basis for nearly all of the applications of linseed oil is its characteristic property of drying. The surface of the oil exposed to air and light rapidly forms a hard dry skin. Wherever, therefore, there is required a vehicle for the incorporation of other substances in an ultimately dry product, linseed oil is used. It has competitors, but they are either inferior or much more expensive. Rosin oil, for example, is frequently used as a vehicle in the preparation of the cheaper grades of printer's inks; but the absence of drying quality in rosin oil is evidenced by the soiled hands that result from the perusal of some of the cheaper newspapers.

The linseed-crushing mills of this country market annually upward of 60,000,000 gallons of oil—nearly half of the world's production, although resulting from the consumption of about one-fourth of the world's flax-seed crop. It is an unwritten law of the industry that a crusher must not be interested in the manufacture or sale of other oils. In no other way can the consumer remain satisfied as to the integrity of the product. This quantity of oil annually produced is sold in raw or treated condition to manufacturers (not to consumers) of paints, varnishes, patent leathers, linoleum, printer's inks, white lead, soap, waterproof stuffs, elastic rollers, enameled shoes, carriage tops, oil silks, etc. It finds a limited use as a lamp or table oil and in the preparation of "bird lime." The raw product, sold principally to paint grinders, has fluctuated in price during the past forty years between 24 cents and $2.03 per gallon, treated oils ranging from 1 to 5 cents higher. When high in price, the applications of linseed oil are strictly limited to those standard and necessary in the established arts; when low in price, the consumption of oil increases immensely and its applications are widespread. Linseed oil is a staple, like wheat or cotton, and its price from day to day may be readily determined by reference to open market quotations. Variations of 1 to 2 cents in the price may occur with various buyers; but variations in excess of this are impossible and point to adulteration. Quotations of 4 or 5 cents under the ruling market price should be absolutely disregarded. No *bona-fide* crusher ever makes such quotations; nor will crushers vary the established 1 per cent 10 day discount rule.

According to Lewkowitsch, extracted (new-process) oils are not suitable for paint grinding. New-process oils are, however, sold to some extent to grinders, and a refined extracted oil is made especially for their trade besides the P. M. P. varnish oil and the two raw oils, "Vacuum" and "Special," the former having had the naphtha driven off under partial vacuum and the latter under pressure. There is a small market for cold-pressed oil, and sufficient demand for oil from Calcutta seed to warrant the seaboard mills in making a short run on such seed every few years.

Paints are prepared in either of two ways — by machinery, at a factory, making "mixed paints," or by hand, by the painter, who combines the color, white lead [1] or other material, as zinc white, and linseed oil "on

[1] White lead is a fully hydrated basic lead carbonate, containing about 69 per cent of carbonate of lead and 31 per cent of hydrate of lead chemically united. The chemical symbol is $(PbCO_3)_2 Pb(OH)_2$. In its manufacture by the usual "old Dutch"

the job" to suit himself. A machine "mixed" paint is the better paint if honestly made, the ingredients being more closely incorporated and more uniformly proportioned than where mixing is by hand. The production of ready-mixed paints in the United States exceeds 70,000,000 gallons annually. Unfortunately, no products are more widely adulterated than mixed paints. Much of the trouble following the use of adulterated paints has been wrongfully attributed to the oil. The function of the oil is to hold the pigment in suspension and to distribute it in a durable and elastic coat. Lead or zinc compounds are added to give body, and thinners like turpentine to facilitate application with the brush, with (usually) various liquid dryers to hasten oxidation.

A paint mixed with white lead alone is apt to powder and "chalk," and is generally considered less durable than one which contains zinc.[1] Mixtures of zinc and lead are commonly used; but in all cases linseed oil is the vehicle for the mixture in a pure paint, to which it imparts the quality of permanence.[2] "Sublimed" white lead (otherwise called "sublimated lead sulphate" or the "oxysulphate" or "basic sulphate" of lead) consists of about 75 per cent of lead sulphate, 20 per cent of lead oxide, and 5 per cent of zinc oxide. "Lithopone" is another white lead substitute or equivalent, but is not often used in ready-mixed paints. Barytes is the most common of all white-lead substitutes; gypsum, whiting, silica, silicate of magnesium, china clay, and other substances are also used. These latter are commonly regarded as adulterations, although it is sometimes contended that a beneficial influence is exerted by the addition of a substance like barytes to a pure white-lead mixture. The thin skin formed by paint upon an exposed surface must be not only dry but elastic, so that it will not blister or crack when the surface is exposed to variations in temperature and moisture. The most perfect

process, metallic lead, cast into perforated disks called buckles, is placed in pots containing weak acetic acid and surrounded by spent tan-bark. The carbonic acid gas given off by the fermenting bark unites with the buckles, changing them to lead carbonate. The "corrosion," as this action is called, requires from 100 to 120 days. The white carbonate is then separated from traces of metallic lead, pulverized, and ground in water. The wet lead may be ground in oil by a process which eliminates the water from the combination, or, as is more usually the case, the lead is dried before grinding in oil.

[1] "Scaling" is the term applied to a condition in which the paint leaves the surface bodily, while "chalking" occurs when the pigment alone remains. When scaling flaking, or peeling occurs, the old coat must be burned off before a new coat is applied.

[2] "There is, generally speaking, but one paint vehicle, and that is linseed oil." — THOMPSON.

elasticity is given by a coat of pure raw linseed oil alone. The introduction of dryers hastens the drying, but impairs the elasticity and durability. Most pigments also have an injurious action upon the oil, and the necessity for color is consequently met by a sacrifice in other qualities. A paint is, therefore, always a compromise, and no paint can ever be entirely satisfactory. The best results are secured by applying paint to a clean dry surface free from grease and soot and from former damaged coats of paint. Green or pitchy lumber or woodwork wet by rain or dew cannot be successfully painted until dry. Painting should not be done in frosty weather. Raw oil should be used in preference to boiled, when weather conditions are such as to promise the necessary time for drying. No addition of dryers should be necessary in the case of a good ready-mixed paint. Priming coats [1] should be applied with unusual care, and should be composed as nearly as possible of pure raw oil,[2] either lead or zinc or color pigment being harmful.[3] Paint should be applied in thin coats, well brushed out, and the coats should be applied in rapid succession. Raw linseed oil is best for mixing, either at the factory or "on the job." If the pigment selected requires the use of a refined oil, one prepared by fuller's earth is best, if obtainable. If weather conditions necessitate the use of boiled oil, this should be a pure oil prepared at the crushing mill by concentrated dryers and in a steam kettle. Either boiled or

[1] Undiluted linseed oil is by some painters regarded as unsuitable for use as a priming coat for metal work. In such applications it dries slowly and loosely. Special paints are commonly used, and much attention must be given to keeping the surfaces clean before applying the paint. See paper by M. P. Wood, "Rustless Coatings for Iron and Steel," Trans. A. S. M. E., XV, 998; XVI, 350, 663. Red lead with linseed oil, however, makes an entirely satisfactory metal primer. Reference may be made to the paper by Cheesman at the convention of the American Society for Testing Materials, June 20, 1907; also to an abstract from the *Farben Zeitung*, quoted in the *Oil, Paint, and Drug Reporter*. 1905

[2] "The essential consideration with the priming or first coat is to secure suitable penetration into the wood. . . . Raw oil should, almost without exception, be used instead of boiled oil for reducing the paint for the priming coat. Raw oil dries slowly and from the bottom up, which allows it to be thoroughly absorbed and to harden uniformly. Boiled oil does not penetrate the wood, owing to its rapid-drying qualities, and hence the coating formed is a surface coating only, and does not become firmly anchored to the wood. . . . The priming coat should be given ample time to dry before applying the second coat . . . nail holes and cracks should be carefully puttied. Cheap putty should be avoided, as it is apt to turn yellow and ultimately crumble and fall out. . . . The paint for the third coat should be of good consistency, with a full raw oil reduction." HOLLEY and LADD, *Mixed Paints, Color Pigments, and Varnishes*. 1908.

[3] A mixture of ten pounds of white lead, two gallons of linseed oil, and one gallon of turpentine is, however, very commonly used.

refined oil should be of standard brands, purchased direct from the crusher or in the original packages. The boiled should cost from 1 to 2 cents over the prevailing price of raw oil and the refined from 2 to 3 cents. Refined oils do not dry as quickly as boiled oils.

Zinc white forms certain water-soluble compounds with linseed oil, and is regarded as unsuitable for use alone on account of the resulting effect of blistering. Zinc, being an extremely active base, reacts strongly with the linseed-oil acids; a mixture of the free fatty acids will, in fact, readily form a hard cement with zinc. White lead appears to be the only pigment ever successfully used alone as a base for paint mixtures.[1] In spite of its one serious drawback, a white-lead coat almost invariably leaves a surface in the best possible condition for repainting. Some bases in combination with oil react so strongly with iron that streaks of iron rust may appear where unputtied nail heads have been left. The bases in mixed paints (white lead, zinc white, etc.) are not chemically united with the oil by mixing; chemical union takes place, if at all, during the drying.[2] The oxidation of oil and of oil paints, which ultimately thickens the mixture, leads initially to a perceptible thinning, facilitating the spreading of the coat. This action may, however, be modified by the action of various pigments. Economy in paint grinding involves the use of a suitable oil — usually one low in free fatty acids. Variations in this respect lead to large increases in the proportion of oil required for a proper mixture. This point must be given especial attention when refined oils are used for grinding. Aside from the question of spreading capacity (i.e., the consumption of paint per thousand square feet covered)[3] the painter is interested in the avoidance of "tackiness" or "livering" in the paint. The "tacky" condition is one in which the undried and unthinned paint has an india-rubber-like resilience, not sticky, but springy. The cause of tackiness is not well understood, but is usually (probably unjustly) attributed to the use of defective oil. "Livering" occurs when oil and pigment are mixed before the grinding is done. It is manifested in a

[1] Zinc oxide ("zinc white") is seldom used alone, because the amount of oil necessary for properly thinning the mixture is so great that the zinc particles are too widely separated to form a thorough covering coat.

[2] The effect of the use of lead in increasing the drying property of the oil is a maximum when the percentage of lead is about .5.

[3] "White lead paste can be mixed with linseed oil in the proportion of 4 gallons of linseed oil to the 100 pounds or of 5 gallons of linseed oil to the 100 pounds, as the condition of the surface may require, and the painter will find comparatively little difference in the ease with which the two paints can be applied." — THOMPSON.

"cheesy" character of mixture, which, however, disappears upon thorough amalgamation. Poorly ground paints may "liver" in the package. They are then "hard" and difficult to work. The ideal grinding is that which thoroughly coats each minute particle of pigment with oil. Many of the "troubles" of painters are due to accidents occurring during or after the application of the coat, from contact with damp or overheated surfaces, from the presence of a moist underlayer as the result of a leaking gutter or leader, etc.

Varnish is "an amalgamation of fossil resins with linseed oil, turpentine, and dryers." This description applies to the better grades, or to what are known more strictly as "oil" varnishes. The gums or resins give strength and body; the turpentine facilitates solution; the oil imparts permanence; and dryers must be used, since only the purest linseed oil is permissible, one that has not undergone such chemical treatment as to impair its elasticity and durability. The gums are dissolved in the solvent by heat, and the oil then added. Besides the pitches, there are used in varnish making not less than fifteen gums, resins, and balsams. These impart hardness and brilliancy to the varnish. They differ greatly in adulteration, solubility, etc. Other substances are often added, like india-rubber, camphor (to facilitate solution), China wood oil (which from its poisonous properties protects woodwork from the attacks of insects), paraffin wax (to decrease brittleness and as an encaustic), celluloid (in cheap spirit varnishes), and metallic resinates (cheaper than natural resins). Various coloring matters are used, some of these being themselves resinous bodies. Various thinning solvents may be used, but these must be employed with caution by the consumer, since some of them cause the resin to separate from the original solvent. Ethyl alcohol, absolute alcohol, ether, methyl alcohol, methylated spirit, acetone, carbon disulphide, naphtha, and turpentine have been used, the last named being generally employed as a thinner. A semi-drying rosin oil is often used in inferior varnishes. This is prepared by an elaborate series of fractional distillations.

The resins are sorted for size, washed, sorted for quality, and crushed. They are usually dissolved over an open fire, since their solubility increases with the temperature; but the use of superheated air or superheated steam has been proposed. In the manufacture of the best varnishes the exclusive use of linseed oil as a medium is almost

universal. With the moisture and breaking tendency removed, and the matter of color properly adjusted, the carefully made varnish oil of the linseed crusher has no competitor. Varnish has been made in this manner for about two hundred years. Its manufacture is a process approaching the status of a fine art, and dependent to an unusual extent upon the absolute purity of the ingredients. The best varnish oil would be cold-pressed linseed oil; but on account of the high cost this is rarely used, and chemically treated oils are employed instead. The treatment should be one that has affected the nature of the oil to as slight an extent as possible; and dark varnish oils are consequently better from this standpoint than the lighter oils. Where lightness of color is essential, a mechanically prepared oil is better than one chemically prepared. Such an oil costs three cents more than raw oil. Good dark varnish oils are sold at an advance in price of one cent. The only requirements for a varnish oil, aside from purity and color, are that it should not break and that it heat quietly, without darkening or foaming, up to the temperature of ignition. The principal defects of varnishes are stated by one writer [1] to be "pitting," "creeping" or "crawling," usually due to oily or greasy or soft surfaces, dampness, coldness, or the presence of acids in the oil, and oftenest experienced with high-grade varnishes; "flatting," "silking" or "enameling," due to a porous surface, a humid atmosphere, or fumes from volatile solvents, to be avoided by imparting "hard" drying qualities; "cracking," due to covering old, inferior coats, to applying too many coats, or to applying the successive coats too rapidly; "roping," or the refusal of the varnish to spread, due to low temperature and drafts; "blistering," due to excessive premature heat or excess of oil or moisture from beneath; "specking," due to freezing; "sagging," due to uneven application or improper mixture of ingredients in the varnish kettle; and "blooming," often caused by dampness. Few of these "troubles" can ever be attributable to the oil; yet many decorators find this a convenient scapegoat for all of the complications experienced in their art. The varnish is prepared by heating over an open fire in large hemispherical kettles. The process is delicate and dangerous, and there are many opportunities for slight errors in manipulation which often result disastrously to the product; but by far the greater part of the complaint following varnishing work is due to

[1] B. E. Miller, in *Proceedings of the New York Railroad Club*, XVII, 4.

errors in the application of the varnish to the surface. The United States Navy specifications (1906) for interior varnish required that it be made from the best grade of hard varnish resins, pure linseed oil, pure spirits of turpentine, and lead manganese dryers only. It must not flash below 105 degrees F., and must dry hard at 70 degrees F. in 24 hours. Most of the cheap varnishes are made by adding 5 or 6 per cent of quicklime to melted rosin and dissolving in linseed or China wood oil. The lime hardens the rosin, and the varnish dries with a brilliant surface, which is, however, easily scratched or cracked.

One important use of linseed oil is as an ingredient of core sands for foundry work. According to A. E. Outerbridge (Trans. A.S.M.E., XXIV, 2) a marked reduction in the cost, skill required, and time of making cores is effected by the use of linseed oil and sharp sand in place of the usual core sand mixed with flour or other binders. The oil and sand are mixed by a centrifugal machine, and the cores require no ramming. They are made by unskilled labor.

The preparation of "white lead in oil" from the white powder produced by the "Old Dutch" or "Bailey" process is a preliminary step in the preparation of paints, the lead being "ground" or mixed in oil in the same manner as any pigment. From 7½ gallons of oil and upward are used per 100 pounds of lead. This semi-prepared lead is found to incorporate more readily than the dry powder with the oil and colored pigment which, jointly with it, constitute the paint.

Linoleum is prepared by saturating linen or fibrous cloth repeatedly in a partially oxidized linseed oil with which pulverized cork has been amalgamated. The oil forms a very thick heavy film to which the cork gives body, and the cloth serves as a guide or form. Specially treated oils are always employed for this application. These are prepared from raw oils, sometimes by the crusher, sometimes by the consumer. The few linoleum and oilcloth manufacturers are the largest individual consumers of linseed oil, and at least one of them is himself a crusher. A single linoleum producer may consume a carload (6000 gallons) of linseed oil per day—practically the output of a 12-press mill.

A high-grade pure linseed oil varnish is generally used for coating insulated cables and for insulation for curved surfaces. These insulations will withstand an e.m.f. of 800 to 1200 volts per mil of thickness. The oil is worked in a series of superimposed cloth layers.

The power factor of the oil varies from .10 to .50. (Discussion of paper by H. W. Fisher, Pittsburg Section, A. I. E. E., Feb. 5, 1908.)

The policy of crushers differs with regard to the production of special oils. Refining is a business in itself. If a mill is so located as to be able to dispose readily of its raw oils, it need not refine. If competition is severe or the near-by market poor, refining may serve to establish a permanent trade. The boiled-oil trade, though rapidly becoming quite insignificant, serves the same purpose as far as it goes. One of the most popular brands of boiled oil in the country constitutes 26 per cent of the total shipments of the producing crusher. Another mill boils only 6 per cent of its oil. The new-process mill treats practically all of its oil, the P. M. P. being the popular brand; but a dark varnish oil and a boiled oil are produced, besides those already mentioned. The trade in this last is very small, on account of the prejudice among paint grinders against extracted oil. A large amount of the new-process oil is sold in the East, although the mill is located at Chicago. Another Chicago mill treats 80 per cent of its product, also shipping largely to the East; while one of the New York mills, which should properly keep the Western special oils out of the New York market, treats only 30 per cent of its output, and even this percentage has been declining. A large amount of oil is handled between mills, one mill marketing, as a tank station, special oils which it does not produce.[1] Thus during 32 months there were shipped from Buffalo to New York 854,000 gallons of oil prepared for the linoleum industry, on which over $10,000 in freight would have been saved if the New York mills had themselves refined this special oil. One New York mill handled outside oils, during three successive years, to the extent of 16, 20 and 18 per cent of its own product. These oils, however, pass through the hands of crushers only, and should not be confused with "second-hand" oil, which is far more often found adulterated.

Freight rates on linseed oil are usually quoted per 100 pounds gross weight, the gross weight in the case of tank car shipments being the weight of oil only. The advantages of such shipments over those in barrels have already been pointed out. Rates are CL or LCL. The CL rate always applies to tank cars and to shipments of not less than sixty barrels, in barrels. Sometimes rates, especially for water transportation, are made

[1] There were shipped to various markets, from Minneapolis, during 1907, over 16,000,000 gallons of oil — more than one-fourth the country's production.

"per barrel"; sometimes a special rate is made per 100 pounds net weight of oil "in tanks." Water transportation is, of course, cheaper; but tank cars cannot be shipped by water excepting for short distances in harbors. Through rates are often made on "rail and boat" shipments, as, for instance, from Buffalo to Savannah, Ga., via New York. The advantage which one mill may have over another with regard to oil freights to a specific market is not as easily determined as would at first appear. The freight on oil from Toledo to Detroit is less, for example, than from Chicago, but the location with respect to seed supply and cake shipment of the Toledo and Chicago mills might easily be such as to enable the latter to deliver oil at Detroit at a lower cost than the former. Each mill should properly know the cost at which it can deliver oil to its own tanks after paying for seed delivered and after packing the cake and delivering it to the buyer. The expense of packing the oil, and the freight, must then be added to the "tank" cost to determine the cost of oil at any stated market. In general, however, the oil moves along geographical lines, based on general averages. Buffalo ships oil to New York, Boston, Pittsburg, and Philadelphia; New York and Philadelphia supply Southern points accessible by water; Chicago, some Southern points reached only by rail. Buffalo or Toledo supplies Cleveland; Toledo or Chicago, Detroit, Dayton, and Cincinnati.

The cost of local shipments in barrels or tank wagons is often relatively high. Motor trucks have been considered for this work. These are usually electrically operated, and can be secured up to five tons' capacity. They are used to some extent by brewers, but the cost of operation is found to be heavy, particularly with regard to maintenance of tires. Under the best conditions, the maintenance expense is about as low as that of two two-horse trucks. The service is fairly good, and free from interruption by ice and slippery pavements. One large truck will do more work than two two-horse trucks. The best service is when the load is heavy and the haul long, as where a mill is located at some distance from the center of distribution. Under such conditions, a motor truck may be expected to effect a saving in the cost of drayage. It may carry oil in barrels or in a tank, or may be convertible to either form. In some cities the trucks may be purchased under "maintenance contracts," by which the truck manufacturer assumes the cost of maintenance upon the payment of a stipulated sum annually.

Complaints regarding linseed oil arise from incorrect weights and

impure oil, besides sometimes from carelessness on the part of the consumer in using the oil. Most complaints are due to trifling causes, and many are of trifling consequence, but all are annoying. Occasionally actual adulteration is found, as in one case where a specific gravity of .90 was observed, and the oil turned green at 500 degrees. This oil had passed through three hands after leaving the crusher. Short weights are often complained of. They are rarely due to intentional misbranding, but often to leakage; sometimes slight shortages occur from soakage, and not infrequently oil is stolen by teamsters and others. Anyone can remove a bung from a barrel and draw off one or two gallons of oil. The usual type and one of the most distressing of complaints is that which comes from some manufacturer who has ruined a quantity of some costly product, like patent leather or varnish, in consequence of some real or imagined defect in the oil. Such troubles are hard to deal with, and the buyer is not apt to accept as final the result of a chemical examination of the oil, which is all that the crusher can do to prove the purity. They would be entirely eliminated if all buyers would inspect and test by simple methods every shipment of oil before using it; and crushers would welcome such a practice as establishing the usual purity of the oil, and drawing attention to any accidentally footy or cloudy oil, which could be returned for exchange before serious damage had been done. Tare weights on barrel shipments are frequently claimed to be underbranded. Such a claim permits of ready investigation, but may be complicated by the question of soakage and by failure of the customer to thoroughly drain the barrels. Cases have been known where an entire barrel of oil has been stolen, the empty barrel afterward being filled with water or something else and delivered to the consumer. The two leading legitimate classes of complaints arise from dirty barrels and improperly filtered oil. A barrel that is not clean, or that is wet, invariably contaminates the oil. Oil drawn from the bottoms of tanks or drawn in cold weather when fresh or after fast filtration is invariably cloudy. Foots, in suspension or as settlement, resulting from this cause or from an attempt to dispose of tank settlings, give good ground for objection. For such defects the crusher is of course responsible. They constitute about the only "impurity" that ever gets into linseed oil from pure flaxseed before it leaves the crushing mill.

Reference is made in a previous chapter to some speculative features of the flaxseed trade. The financial status of the linseed industry, it is

believed, would be strengthened by the "plan to enable the crusher to sell his main product, i.e., raw linseed oil, on the commercial exchanges of the country, where under the strict rules of these markets he buys the bulk of his raw material. Safe methods could be devised for warehouse receipts, as secure to the holder, or banker, as any warehouse collateral, properly safeguarded as to quality by inspection. Commercial exchange in linseed oil would open opportunity in what may be claimed as legitimate speculation by the consumer, who could in this field hedge his requirements on the staple article, or sell, and repurchase; while for special or refined oils he could transact business with the crusher direct. This method of trading would steady the price of the jobber, as good judgment would suggest transactions on exchanges should not be for less than 5000 gallons or the equivalent of that quantity." The rules regulating transactions in linseed oil among members of the New York Produce Exchange, adopted July 21, 1904, are intended to meet these requirements, so far, at least, as the New York trade is concerned.

English (and other foreign) prices for linseed oil are usually quoted per 2240 pounds (ton) or per 112 pounds (cwt.). The price in cents per gallon of 7½ pounds equals 1.62 times the price in shillings per cwt., or .081 times the price in shillings per ton; the pound sterling being taken equal to $4.84, worth 20 shillings.

CHAPTER XX.

THE FEEDING OF OIL CAKE.

Uses of cake.—Its geographical distribution.—Analysis.—Adulteration.—Meal.—Theory of feeding.—Specification for linseed cake.—Comparison with cotton seed cake.—Compound cake.—Methods of analyzing cake.

THE only use for linseed cake is as a food for live stock, especially for dairy cattle. Its value for this purpose is of the first importance. Excelled in nutritive value only by cotton-seed cake, and superior to the latter in special dietetic properties, it is the favorite feed of the most successful stock-raisers. The cake contains from 30 to 36 per cent of protein, of which about 85 per cent is digestible, and the nutritive value is consequently three or four times that of hay. The percentage of fat varies from 4 to 8. Although used extensively abroad, American farmers apparently have little appreciation of the value of linseed cake. Only about 20 per cent of it, nearly all of which is in the form of meal, is retained for home consumption, although the fertilizing value alone of the manure from the cake is estimated at over $16.00 per ton. The domestic demand is slightly but steadily increasing. The principal foreign demand is from Belgium, with Holland as a close competitor. These two countries take annually about 60 per cent of the total exports of linseed-oil cake from the United States. In Belgium, at least, linseed cake has practically superseded the once more familiar cotton-seed cake. The United Kingdom furnishes the third market, although the more popular feeding stuff there is the cotton-seed cake. In 1895 England took 84,000 tons of linseed cake, and in 1901 only 49,000 tons, the decline having been almost without interruption. During the same period England's imports of cotton oil cake from the United States increased from 78,000 tons to 156,000 tons.. The English prefer a cake having a high percentage of oil. This they obtain in cotton oil cake, which is, moreover, sold at about the same price as linseed, or even at a slightly lower price. Oil cake is also exported from this country to France and Germany to the extent of about 30,000 tons per year for both countries. A slight

amount is shipped to the West Indies and Canada, probably not over 5000 tons annually. The average annual exports of linseed cake from the United States to all countries for the five years ending June 30, 1902, amounted to 244,000 tons, valued at $5,665,000. Denmark imports no linseed cake whatever.[1] Of the six principal oil cake consuming countries of Europe, Belgium, Holland, and France may be classed as linseed oil cake importers, and Germany, the United Kingdom, and Denmark as cotton seed cake importers. The Danes claim that when cows are fed on linseed cake the butter obtained from their milk is invariably less delicate in flavor. For fattening purposes, however, they admit that linseed cake is the best feed, although they do not buy it on account of its high price. Japan offers a large market for oil cake, now supplied chiefly from China and India. The imports for 1904 were 100,000 tons; for 1905, 235,000 tons; for 1906, 320,000 tons. England buys no linseed meal, preferring the cake on account of the decreased probability of adulteration, and because it results in practically no loss when feeding in the open, as is the usual practice. The total exports of meal from the United States are insignificant.

Linseed oil cake is produced in the following competitive and noncompetitive countries: Russia, Germany, Poland, France, Spain, the United Kingdom, Holland, Belgium, Egypt, India, Peru, Chili and the Argentine.

Laws regulating the sale of feeding stuffs are in force in most of the states of the Union. The usual adulterants of linseed cake are sand, rape seed, cake bran, and elevator screenings. The adulterations are not all harmful. Following are comparative analyses of pure and typically adulterated samples of linseed meal. (Adulteration with elevator screenings.)

COMPARATIVE MEAL ANALYSIS.[2]

From —	A (adulterated).	B (pure).
Water	9.25	8.50
Ash	1.00	.85
Protein	35.02	32.96
Fiber	9.60	9.15
Fat	6.75	7.35
Starch	38.38	41.19

[1] The monthly receipts and exports of oil cake and meal are regularly recorded in the annual statistical reports of the New York Produce Exchange.

[2] Note that the percentage of protein is in favor of the adulterated sample.

A sample of "new-process" meal gave, in parts per 100, water 9.18, ash 4.90, oil 1.50, fiber 9.04, albuminoids 41.60, carbohydrates 33.78. A foreign analysis of a meal stated to be impure gave oil 4.3, moisture 10.5, albuminoids 33.7. The meal contained about 13 per cent of chaff and straw-like particles. Linseed meal is much more easily adulterated than cake, as the only way of putting foreign substances in the latter is to introduce them before the flaxseed is pressed.

What trade there is in the United States in linseed cake is nearly entirely meal trade. In order to introduce the product to American farmers, it has been sold rather more cheaply than it should have been. The actual cost of making one ton of meal is from ninety cents to one dollar, not including shrinkage. Not less than 60 horsepower is required to operate a grinder crushing 100 tons per 24 hours. The shrinkage in grinding cake is heavy.

Theory of Feeding.

"Comparisons of different kinds of foods are usually made on a dry or water-free basis, which shows the percentage of food ingredients in the dry matter. Ash is what is left when the combustible part of a feeding stuff is burned away. From the various constituents of the food the digestive organs of the animal select those which the animal needs and the rest is voided in the manure. Fat,[1] or material which in analysis is dissolved from a feeding stuff by ether, includes, besides real fats, wax, the green coloring matter of plants, etc. For this reason the ether extract is usually designated 'crude' fat. Carbohydrates are usually divided into two groups: (1) Nitrogen-free extract, including starch, sugar, gums, and the like; and (2) cellulose or fiber, the essential constituent of the walls of vegetable cells. The carbohydrates form the largest part of all vegetable foods. They are not permanently stored up as such in the animal body, but are either stored up as fat or burned in the system to produce heat and energy. They are one of the principal sources of animal fat. Protein (or nitrogenous material) is the name of a group of materials containing nitrogen. All other constituents of the feeding stuffs — the ash, fat, and carbohydrates — are non-nitrogenous or free from nitrogen. Protein[2] materials are often designated as 'flesh formers,' because they furnish the materials for the lean flesh; but they also enter largely into the composition of blood, skin, muscles, tendons, nerves, hair, horns, wool, the casein and albumen of milk, etc. For the formation of these materials protein is absolutely indispensable. No substances free from nitrogen can be worked over into protein or fill the place of protein. It is, then, absolutely necessary for an animal to be provided with a certain amount of protein in order to grow or maintain existence. Protein, like its counterpart, the nitrogen in fertilizers, is the most expensive element in food, and a considerable amount of it is absolutely essential to growth.

[1] "Fat is the fat or oil of the material, and its office is the production of fat and heat in the animal system."

[2] "Protein is the nitrogen-containing albumen-like substance of plants, similar in composition and character to the white of an egg. It is the most costly form of food, and, generally speaking, has for its function the formation of flesh and muscle."

"A ratio furnishing the protein, fat, and carbohydrates in the right proportion is said to be a 'balanced' ration. If it contains too much carbohydrate and too little protein it is not well balanced. In addition to furnishing the requisite amounts of nutrients the food must have a certain bulk. The required bulk is secured by feeding a certain amount of coarse fodder, which aids digestion and helps to keep the animal satisfied and healthy. The measure of the bulk or total solid matter is the weight of dry matter in the ration. The dry matter is the solid or water-free portion of the food. More latitude is allowable in this with a diluted balanced ration than in the case of any single nutrient."

The cake obtained as a by-product in the manufacture of cotton-seed oil is practically the only competitor which linseed cake is obliged to meet as a concentrated feed. Cotton-seed cake is much more variable in its composition than linseed, the protein ranging from 23 to 53 per cent and the fat from 2 to 21 per cent. Such variations would be entirely inadmissible in the linseed industry. The average fertilizing values of the two cakes, in pounds per ton, of nitrogen, phosphoric acid, and potash, respectively, are stated to be, for linseed, 106, 39, and 20; for cotton seed, 135, 61, and 36. A test of new-process linseed meal, however, gave the figures 68 to 88, 20 to 24, and 20 to 22; while the results of 204 analyses of cotton-seed meal gave 63 to 162, 25 to 92, and 17 to 66, the variation in results being due to the wider distribution of the cotton-seed industry and consequent wider variations in seed and in the method of mill operation. Cotton-seed meal or cake may not safely be fed to young calves and growing animals, and may never be fed alone without roughage.[1] It does not possess the condimental qualities of linseed cake. The cotton-seed industry in the United States resembles the linseed industry abroad in the relatively low price of oil and high price of cake; and these conditions give rise to methods of operation resembling those of foreign linseed crushers, making the cake competition severe. A broadened domestic market for linseed cake may result as the operation of cotton seed oil mills becomes adapted to higher yields of oil, or may follow any considerable reduction in the price of flaxseed; no other conditions, apparently, can lead to a large domestic consumption of linseed cake.

Compound cakes, composed of a mixture of ground cakes of various kinds adapted to the production of a balanced ration, heated and pressed into form, present many advantages from the standpoint of

[1] Experiment Station Bulletin No. 11 of the United States Department of Agriculture places linseed meal next to cotton-seed meal both in protein content and in protein plus fat. In fertilizing value, the same bulletin ranks linseed meal at $19.70 per ton.

the feeder, who may thereby secure a cake of the exact form, texture, weight, and composition desired. Their production has been developed on an extensive scale in England, but not at all in this country, and the matter is at present of slight interest to the crusher.

Certain established brands of linseed cake have become so popular among Continental buyers as to frequently command a premium, and even where they do not command a premium the advantage of having a prize brand is very great, especially at times when there is little demand for cake. Some of the requisites of popularity for linseed cake are given in Chapter VIII, page 120.

The analysis of feeding cakes consists in the determination of moisture, oil, ash, and protein. The following methods apply:

Moisture. — Heat a sample for three hours in an evaporating dish placed in an oven or bath having a temperature of about 225 degrees F. The loss in weight is moisture.

Oil. — The ordinary "cake test" is made, as described on page 126. Dry meal remaining from the moisture test should be used as a sample.

Ash. — A sample is burned on a porcelain dish. The residue is ash.

Protein. — This determination requires a considerable degree of skill and experience. The Kjeldahl method is commonly used. As described by Olsen,[1] this consists in digesting the sample with sulphuric acid, distilling the ammonia thus produced, and

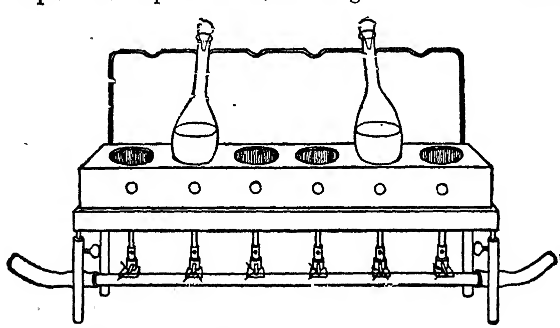


FIG. 59. — KJELDAHL DIGESTION FLASKS.

determining the nitrogen by means of standard sulphuric acid. Fig. 59 shows the digestion flasks; Fig. 60, the same flasks ready for distillation. One gram of the finely powdered cake is placed in the digestion flask, 1 gram of metallic mercury or about 0.7 gram of mercuric oxide is added, and 25 c.c. of a solution of 200 grams of phosphorous pentoxide in 1 liter of concentrated sulphuric acid (sp. gr. 1.84). After digesting and transferring the acid to the distillation flask (unless the digestion flask itself is of sufficient size), there are added 200 c.c. of water, and the mercury is precipitated by adding 25 c.c. of a solution of 40 grams of potassium sulphide in 1 liter of water. The acid is then neutralized by the addition of a saturated solution of caustic soda, of which

[1] *Quantitative Chemical Analysis*, J. C. Olsen. D. Van Nostrand Company.

about 50 c.c. will be required. After the addition of a few grams of granulated zinc th ammonia is distilled into the sulphuric acid, of which 50 c.c. of $\frac{N}{5}$ acid[1] is usually ampl The excess of acid is titrated back with $\frac{N}{5}$ or $\frac{N}{10}$ alkali.[2] (Wilfarth's modification c Kjeldahl's method.) The nitrogen found is calculated as protein by multiplying b the nitrogen factor 6.25.

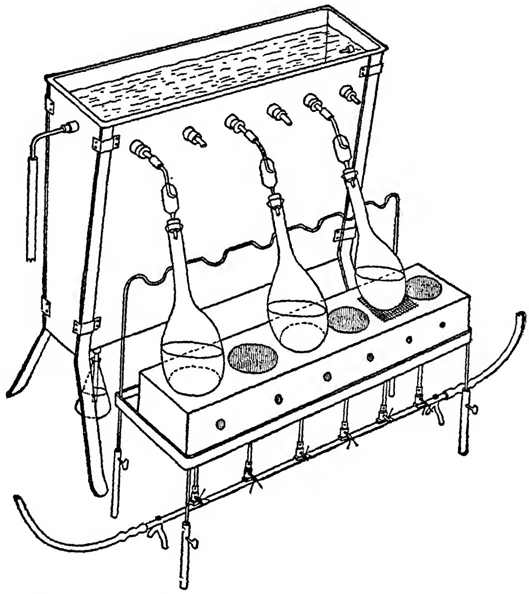


FIG. 60. — DISTILLATION OF NITROGEN EXTRACT.

The percentage of fiber is occasionally determined, though no usually. The carbohydrates are ordinarily estimated by difference.

Foreign buyers usually determine the percentage of ash in the cake and also make an extraction with boiling water, noting color, taste, an smell of the extract, the presence of starch (detected by an iodin solution), etc. A sample is also treated successively with nitric aci and sodic hydrate, and the residue subjected to microscopic exami nation. Impurities in the original sample are also detected by th microscope.

[1] Olsen, *op. cit.*, p. 261.

[2] Olsen, *op. cit.*, p. 266. These standard solutions may be purchased, ready for us from the chemical supply houses.

CHAPTER XXI.

MISCELLANEOUS SEED OILS.

Minor expressed oils. — Saponified red, castor, sesame, olive, hemp, walnut, poppy, palm, essential oils.—Peanut oil.—Sunflower oil.—The sunflower plant.—The cake.—Yields.—Composition of sunflower seed.—Mustard oil.—Copra.—The copra industry.—Cocoanut-oil products.—Preparation of copra.—Rape oil.—Production of seed. — The cake.—Economic importance of these oils.

THE expression of oils from other seeds is generally conducted by machinery and methods similar to those which have been described. It is not customary in this country for a manufacturer to produce more than one seed oil, however, in spite of the similarity of operation and of the further fact that the total (not active) expressing equipment of the country considerably exceeds in capacity any possible output that the market can take care of. The mechanical phases of seed crushing, as has already been suggested, are of relatively minor importance. The important points are the obtaining of the maximum yield (which requires special experience with each seed) and the commercial operation of the business.

Among the less important oils, derived from seeds or otherwise, which are obtained by expression, the following may be mentioned.

SAPONIFIED RED OIL. — This is obtained as a by-product in the preparation of candle fats. It requires special machinery and a refrigerated room.

CASTOR OIL. — Requires two pressings. The oil from the second pressing is used as a lubricant. The cake is all ground and used as a fuel or fertilizer. The castor bean is successfully grown in California, but is generally imported from British India. A report of the United States Department of Agriculture (C. W. Daugherty, 1905) discusses the commercial possibilities. There are several crushing establishments in this country.

SESAME OIL. — The sesame seed contains more than 50 per cent of oil, and is usually given three pressings, the first producing a high-grade table oil, and the last two, soap stock. The seeds are brought

from India and the Levant, and the oil is very cheap. A large amour of the oil is brought to the United States from Marseilles.

Olive Oil. — This is invariably pressed where the olives grow.[1]

Hemp. — The plant grows in North America. The cake has littl value. The oil is used for dark, inferior paints and varnishes and fc soap. Its properties have been studied by Lewkowitsch.

Walnut Oil. — This is given two pressings, the first making high-grade table oil. The second-pressed oil has superior dryin properties, and makes a brilliant lamp oil.

Poppy Oil. — Is given two pressings. A drying oil. Used for soa]

Palm Oil. — The palm nuts are deprived of the outer skin an hard shell, and then contain from 49 to 52 per cent of oil. Two pres ings, or a combination process of pressure and extraction, are use On account of the high color, palm oil is used for mixing with ole margarine, being first thinned with cotton-seed oil.

Essential Oils. — The principal of these is the oil of bitt almonds, for which peach-kernel oil and apricot-kernel oil are su stitutes. The consumption is very small.

The extraction of oil from corn germs has already been referred t The gingelly and niger seed oils are of some importance. The latter considered edible in parts of Asia. It is imported into the United Stat under a 25 per cent duty. Oil of nutmeg is occasionally met with; a an oil of minor commercial importance has been extracted from t Jerusalem oak or common "jimson weed." An oil extracted from t pine has been used as a substitute for turpentine. Lewkowitsch gi the principal characteristics of lallemantia, walnut, poppy, niger, madia, and various less important expressed oils. Most of these requ two or more pressings, and in order to obtain an extremely clear oil fr the first pressing a press of the "cage" type shown in Fig. 61a commonly used.

Rice oil is made from the bran of the rice kernel, which contains ab 15 per cent of oil. It is a green semi-solid body of high acid value. T specific gravity at 99 degrees is from .8907 to .9075. It melts at degrees, and has a saponification value from 189.3 to 193.5 anc Reichert-Meissl value of 1.1. It is suitable for making soaps or cand but is low in neutral glycerides and therefore yields little glycerine.

Beechnut oil is an edible oil derived from the nuts of the beech t

[1] See paper by R. I. Geare, in the *Oil, Paint, and Drug Report*

These contain 67 per cent of kernel, which shows from 28 to 43 per cent of oil. Decortication is not necessary. The oil may be expressed cold or hot, the maximum yield being about 400 kilos of oil per acre of trees. It is not a drying oil. Its specific gravity is .9225. It freezes at 17 degrees C., and keeps well. The hot-pressed oil may be used for white soaps or for lighting. The cake is poisonous to cattle, on account of the alkaloid "fagine," which exists in both kernel and shell.

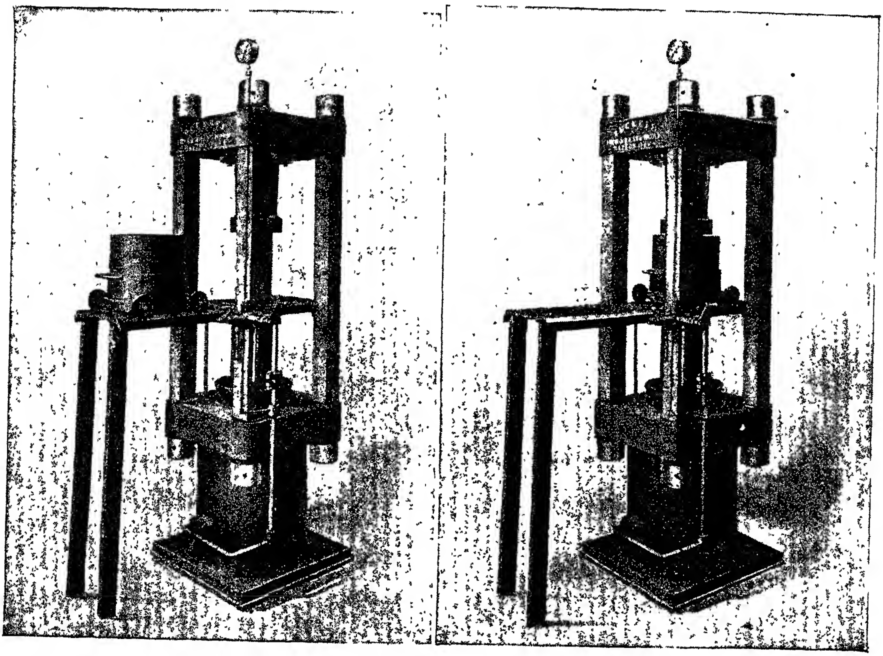


FIG. 61a. — CAGE PRESS.

Wild-almond oil is used as a salad oil in India. The trees produce 500 pounds of dry kernels per acre, yielding 50 per cent of oil. There is no extended market for this oil, which keeps well and may be crushed with or without the shell.

Pumpkin-seed oil, of a reddish green color, not easily bleached, and is occasionally used as an edible or preservative oil. The shell contains 77 per cent of meat, which yields 48 per cent of oil. The iodine number ranges from 116.5 to 120.5. The cake contains 38 per cent of protein.

China wood oil has been discussed in Chapter XVI. Six remaining oils are of especial importance.

Peanut Oil. — An actual yield of from 38 to 39 per cent of oil is obtainable from peanuts. They are usually expressed in France. It is stated that a price of 2½ cents per pound of shelled kernels may be realized by the American grower. The oil is worth from .3 to .4 franc pe kilo. It rapidly becomes rancid. The kernel of the American nut is high in moisture. This makes it difficult to grind and damages the press mats. The shrinkage in production, due to the difference in moisture of seed and cake, is usually about 2 per cent. The seed is given two pressings. To facilitate grinding American nuts are sometimes mixed with the dryer Coromandel kernels. Kernels from the Orient are frequently received water-soaked or otherwise adulterated. The nuts are passed through an ordinary cleaner, then ground and pressed without heating. A single pressing, lasting about forty minutes, may be given This, however, produces an inferior oil, suitable only for soap stock, and a cake showing 10 per cent of oil, the method being regarded, generally as less profitable than double pressing. With such double pressing, the first run of oil is suitable for use as a salad dressing. The second run gives an equal quantity of oil, available for soap making. The cake is used for feeding milk cattle and hogs. In the Marseilles market the price of the oil is usually slightly higher than that of sesame oil. The center of the peanut trade in the United States is at Norfolk, Va., where enormous quantities are marketed annually, largely for export. There are a few peanut-oil mills in this country, operated generally by manufacturers of peanut candy.

Sunflower Oil. — The expression of oil from the sunflower seed is described in Bulletin No. 60 of the United States Department of Agriculture, "The Sunflower Plant," by Harvey W. Wiley. The status of the industry in Russia is shown in United States Consular Report No. 137, February, 1892, p. 233 — report of Consul John Crawford of St. Petersburg, entitled "The Sunflower Industry of Russia."

There is no mill in this country devoted to the manufacture of oil from sunflower seeds.

The wild sunflower, *Helianthus annuus*, from which the cultivated variety has been developed, is native in the Great Plains region from Nebraska to Northern Mexico. In Russia, the sunflower seed has become almost a staple article of diet. It is eaten raw or roasted as peanuts are in America, but much more extensively.

The oil cake left after the extraction of the oil by pressure is extreme

rich in nitrogenous matter, has a high food value, and it is extremely palatable. It is eaten by cattle with avidity.

The production of seed in Russia is at present estimated at 228,000,000 pounds annually. The sunflower seed is also cultivated in immense quantities in Italy, India, Tartary, and China. The oil is competitive with peanut oil. The Russian seed is usually expressed on the spot where it is growing, and the oil is largely employed for adulterating olive oil. The purified oil is considered equal to olive and almond oil for table use. The chief industrial uses are in woolen dressing, lighting, and candle and soap making. For the last mentioned purpose it is of special value. It is pale yellow in color, thicker than hemp-seed oil and dries slowly. Its physical and chemical constants have been recorded by Lewkowitsch.

An average yield of seed of from 1000 to 1500 pounds is obtainable, the usual range being from 1250 to 1350 pounds per acre. The price of seed in the United States is usually in the neighborhood of 2 cents per pound. Sunflower seed, like cotton seed, is liable to fermentation and heating if stored in bulk after the outer husk has been removed. For this reason the seeds after separation should be kept in barrels or very small bins, and should even then be turned over two or three times a week.

Experimental culture in France of the sunflower gave a return as high as 1778 pounds of seed to the acre, yielding 15 per cent of oil and 80 per cent of cake. This percentage of oil is, of course, in the unhulled seed. The excessive shrinkage is no doubt due to the high proportion of moisture in the seed.

COMPOSITION OF SUNFLOWER SEED.

	Air-dry.	Dried.
	Per cent.	Per cent.
Water	12.68	....
Ash	3.00	3.43
Albuminoids ($N \times 6.25$)	15.88	18.19
Crude fiber	29.21	33.45
Nitrogen-free extract	18.71	21.43
Fat (ether extract)	20.52	23.50
Total	100.00	100.00

The sunflower plant is one which rapidly exhausts the soil.

Mustard Oil. — This oil is sold largely as a substitute for rape oil. The imports of mustard seed (cultivated) have been increasing. The price fluctuates quite widely, being usually between 2 and 4 cents per pound. The cake is ground, and is used for medicinal purposes and for the table. It is a far more important product than the oil. The yellow German mustard seed makes the best mustard (i.e., ground cake), which may show as high as 35 per cent of oil. For plaster mustard, the Trieste or brown German seed is used. The following results were noted by the writer in working 35,031 pounds of ordinary (American) wild-mustard seed, containing about 6 per cent of impurities, in a linseed-oil mill:

This seed cost $21 per ton gross, or practically 59 cents for 56 pounds, from which outputs were obtained as below:

Net weight of cake, 25,961 pounds, or a yield of 41.53 per 56 pounds of seed.

Net weight of oil, 9070 pounds, or a yield of 14.51 per 56 pounds of seed.

A test of the cake showed the presence of 5.65 per cent of oil.

This seed was ground with rolls in the ordinary way, except that it was fed very slowly. It was attempted to temper the meal in the ordinary way, but no moisture could be used, as the wet meal would squeeze out when subjected to pressure. For the same reason, the meal would not stand a temperature of over 140 degrees while in the heater. The nearer cold and dry the meal is worked, the better is the result obtained. The pressing of mustard seed in linseed presses was found to be at least one-half more destructive on press cloths than flaxseed. The cloths adhered to the cakes so firmly that some injury accompanied the stripping. The pressure used was 3600 pounds per square inch. The best treatment would undoubtedly include two pressings, the cold-pressed oil being made first.

Copra. — The dried meats of the cocoanut are rich in a highly valuable oil which is rapidly becoming of commercial importance. These meats are known as copra or coprah, and the resulting oil is cocoanut oil. Cocoa butter is not derived from copra or the cocoanut, but is a product of the cocoa bean.

The United States import duties are as follows:

Copra (dried cocoanut meats)	Free
Copra (desiccated, shredded, cut, or similarly prepared)	2c. per lb.
Cocoanut oil (as oil of nuts)	Free
Cocoanuts in the shell	Free

The duty of 2 cents per pound on prepared cocoanuts is subject to a discount of 20 per cent, making the net duty 1.6 cents per pound. The imports of cocoa butter pay a duty of $3\frac{1}{2}$ cents per pound. While the increasing markets for cocoanut-oil products have resulted in a recent large increase in importation of this oil, even this fast increase has been insufficient to keep up the supply. The import of cocoa butter has similarly increased. Cocoa butter, strictly so called, derived from the cocoa bean, is frequently imitated by cocoanut butter, a condensed form of the cocoanut oil, blended, usually, with animal fats. In addition to the heavy imports of cocoanut oil, a considerable amount of copra is imported. Generally speaking, the importation of copra is profitable only on the Pacific coast, it being cheaper, in the neighborhood of New York, to import the oil.[1] The world's supply of copra is derived from the Philippines, Tahiti, Java, Samoa, the Dutch colonies in the Indian Ocean, and, to a slight extent, from Cuba. The exportation from Cuba has been declining. Baracoa is the Cuban shipping point. The importations of the oil are brought into this country in very long casks, called pipes, holding from 2000 to 3000 pounds. Enormous quantities of copra are imported in Europe, principally by France and Holland. The principal European crushing point is Marseilles. Large exports of cocoanut oil are made from Marseilles to the United States. The average price of cocoanut oil in Marseilles is from .5 to .7 franc per kilo.

The cocoanut (*Cocos nucifera* Linn) has been reared as far north as Indian River, Florida, latitude 28 degrees N., but has not proven a profitable commercial venture oustide the tropics.

According to the reports of the American consul at Marseilles, the conversion of cocoanut oil into dietetic compounds was undertaken in that city in 1900 by Messrs. Rocca, Tassy & De Roux.

"These articles are now produced at a gross price of 18 to 20 cents per kilo, shipped to Dutch traders, and at the added cost of a cent or two, repacked in tins branded 'Dairy Butter' and shipped to all parts of the world. Cocoanut oil was once used extensively in the manufacture of fine candles. It is still in occasional use as a street illuminant, and when fresh is an exceptionally good cooking fat. The medicinal uses of the oil are various. The exportation of copra from producing countries is detrimental to the best interests of the planter, tending to enrich the manufacturer and impoverish the grower. The causes which favor the exportation of copra rather than the oil from the Philippines are:

[1] There are two cocoanut-oil mills on the Pacific coast and one in Philadelphia.

"First. — High cost of oil milling plants.
Second. — High cost of packages and difficulty of getting them returned.
Third. — Lack of good roads, making shipment of the oil expensive.
Fourth. — Absence of a market for the cake.

"The cocoanuts are first stripped of their fibrous husks and shells, and the meats are then heated in the sun or by means of a fire. These dried meats are the copra, ready for shipping abroad to the crusher, or for local expression. Rasping and grinding machinery of many patterns and makes, for reducing the meat to a pulp, is used in India, Ceylon, and China. In the Philippines, when the oil is to be expressed locally, the fleshy halves of the meat are held by hand against a rapidly revolving, half-spherical knife blade which scrapes and shaves the flesh down to a fine degree of comminution. The resulting mass is then macerated in a little water and placed in bags and subjected to pressure, and the milky juice which flows therefrom is collected in receivers placed below. This is now drawn off into boilers and cooked until the clear oil is concentrated upon the surface.[1] The oil is then skimmed off and is ready for market. Not less than 10 per cent of the oil goes to loss in the press cake, which makes an acceptable stock food.

"The freshly ground cocoanut fruit contains 35.4 per cent of oil. The amount of cellulose (fibrous matter) is only 3 per cent, and it is readily digestible when the mass, by grating, is reduced to a fine degree of comminution.

"The average market value of the best grades of copra in the Marseilles market is $54.40, gold, per English ton. The jobbing value of the refined products may be roughly estimated for each ton of copra:

Butter fats	$90.00
Residual soap oils	21.00
Press cake	5.20
Total	$116.20"

Many valuable data may be derived from the exhaustive pamphlet by W. L. Lyon on "The Cocoanut" (Manila, 1903), published as Bulletin No. 8 of the United States Department of Agriculture.

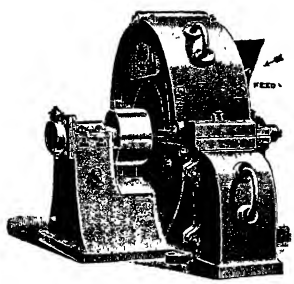


Fig. 61. — Copra Disintegrator.

Fig. 61 represents the "disintegrator" used for rasping and grinding the copra. The grinding is done by percussion. The material is fed in at the periphery of the grinding chamber and, falling on the extremity of the beaters, which travel at a speed of about 15,000 feet per minute, is pulverized by them, or by being beaten against the serrated chilled-iron linings of the upper half of the chamber, or the steel bars of the screens which form the lower half. Although the beaters are at a distance of about one inch from

[1] The oil rapidly becomes rancid, and must not be exposed to the air. Tests for purity are described in *Les Corps Gras Industriels*, 1905.

the case, the material is ground, by impact only, to an impalpable powder. The machine has a capacity of 2800 pounds per hour, and weighs 9000 pounds. Smaller sizes are also built. A very similar machine has been found to be best adapted for the grinding of linseed cake. Another ingenious machine cuts through the husk, shell, and kernel of the cocoanut, just as gathered, at one operation. This is known as the "splitter." It greatly facilitates the removal of the copra from the husk and shell.

Rape-seed Oil. — Rape seed, or colza, or ravison, is imported into the United States duty free.[1] There is a tariff of ten cents per gallon on the oil. The consumption of the oil in Europe is considerable, ranking until recently next to linseed. It is used for a great variety of purposes, as an illuminant, for soap making, etc., but in this country its consumption is limited to the compounding of high-grade lubricating oils. The United States imports annually sufficient amounts of the seed and of the oil (mostly the latter) to justify the erection of a large mill. There would be a considerable profit in crushing the seed in this country so long as the present tariff on the oil continues. At present writing the seed is quoted at 32*s.* 7½*d.* per quarter (416 pounds) c.i.f. Antwerp. This is equivalent to $1.06 per bushel of 56 pounds. Adding four cents per bushel for freight, etc., the seed would net $1.10 f.o.b. New York. The oil is quoted at £22–5–0 per ton, equivalent to $.0481 per pound. Adding to this the duty, $.0125, and the freight, $.0025, the oil, f.o.b. New York, is worth $.0631 per pound at a price of $1.10 per 56 pounds for seed. If the cake nets $20 with a working cost of 25 cents and a 19-pound yield of oil, the oil will cost per pound $.0511, making a difference between this figure and the cost of the oil imported of $.0120. If cake must be sold for $15 the margin will be $.0071.

Rape seed is produced principally in Russia and British India; to some extent also along the Danube River and in France. The non-producers in the crushing countries obtain a large portion of their supplies from India. The Indian rape-seed crop ranks next in importance to that of linseed. There are many grades of seed, differing in price and correspondingly in percentage of oil. Most of the world's crop of rape seed is shipped to Germany. The united consumption of France, England, and Holland, each of which countries takes about the

[1] Prior to 1891 there was a duty of one-quarter cent per pound on the seed.

same quantity, is less than that of Germany. The seed is usually shipped in bags holding about 100 kilos, and the terms of sale are those of the Liverpool 4 per cent sound delivery contract. (See p. 212.)

A considerable amount of the seed is used for other purposes than for oil expression. Various samples of rape seed, tested for percentage of oil, show much greater variations than flaxseed. One sample gave 44 per cent, another sample 39 per cent. A sample of domestic wild rape seed tested 33.6 per cent.[1]

Seed.	Price per Qr.	Per cent of Oil.
Brown Calcutta	30/	42 3
Brown Cawnpore	31/	43 5
Ferozepore	31/	44.0
Yellow Cawnpore	33 3	44 0
Yellow Guzerat	33.9	44 1

In a trial run on imported German seed, while the quantity was so small that a fair yield was not obtained, the oil was of good quality, and when subsequently treated by blowing was pronounced satisfactory for the compounding of lubricating oils. The only novel feature observed in working the seed was that the proportion of superficial moisture was so great that the material had to be run dry in the heaters.[2]

The cake produced from rape seed is not popular as a feeding material, and is practically all used as fertilizer. The London price is usually in the neighborhood of $15 per ton.

The blown rape oil produced in the experiments referred to had an average specific gravity at 60 degrees F. of .968. A sample of imported blown rape had a specific gravity of .973.

There is very little, if any, domestic wild rape seed sold as such on any of the seed markets of this country. What we call wild mustard is frequently referred to as rape seed. One could not secure enough genuine rape seed in the market to make it worth while to do anything with it, but wild mustard seed can be obtained in abundance. In a single season 100 carloads have been sold in the Minneapolis market. All of the mustard seed produced in this country contains a large portion of rape seed proper, but the two are not separated. The

[1] Tests made in July, 1904, on various grades of East Indian rape seed.

[2] Two successive pressings, the first on cold seed, would have been better. This is the practice of German crushers.

size and color of the two seeds are almost identical. Mustard and rape seed each contain about 35 per cent of oil. There is scarcely a sufficient quantity of pure rape seed produced in this country to supply the demand for birdseed.

Efforts have been made, repeatedly, in this country to manufacture rape oil; but they have always failed, first, on account of the difficulty of disposing of the cake or meal, and second, because of the fact that the supply of seed is monopolized by English manufacturers. It is claimed that only East India seed will give an oil having the necessary properties, and that an oil made from other seed would be unsatisfactory for lubricants. A portion of the duty on rape oil is rebated as a drawback on export shipments of lubricating oils.

The United States is deferring, if not missing, an opportunity for increasing its productiveness by reason of the scanty attention given these oils. Of those mentioned, the walnut, poppy, gingelly, niger, and various essential oils are perhaps of minor importance; while the olive, palm, and saponified red oils require special treatment or special location which remove them from the scope of this review. Olive oil, however, should be produced advantageously in California in greater quantities than at present. In castor and mustard oils we are perhaps fairly active. With hemp, sunflower, sesame, and peanut oils we are doing practically nothing. The last named we certainly should produce, rather than export the kernels, as we now do, probably importing their product later on as olive oil. These oils, with that from copra, are particularly desirable for the production of high-grade soap stocks, as well as for healthful table oils. On our Pacific coast the cocoanut-oil industry should be much more important than at present, while in the East the extraction of peanut oil should be profitable. Our most conspicuous failure is in the importation of rape oil. This we could and should produce on equal terms with the foreign crusher, and particularly with a 10-cent duty on imported oil in our favor.

The general neglect of the miscellaneous seed oils contrasts strongly with the immense development of the cotton-oil industry, described in the following chapter.

CHAPTER XXII.

THE COTTON-SEED INDUSTRY.

The industry.—Process of preparing the seed.—Cleaning.—Pulling.—Crushing.—The oil. —Refining.—The cake.—Meal.—Cost analysis.—Products from one ton of seed.— Purchase of seed.—European practice.—Hulls.—Plans of typical mills.

THE manufacture of cotton-seed oil differs in some respects from that of linseed products. The cotton-oil industry in the United States is a large one, twice as large as that in linseed. The underlying principles of operation are in some respects different, as has already been intimated (page 9). The present brief reference to some of the more marked differences may well be supplemented by reference to the work of Lamborn,[1] as well as to the paper "Cotton Seed and Its Products" published as Bulletin No. 36 of the United States Department of Agriculture. From these publications the writer has selected freely.

The cotton, after being harvested, is ginned to separate the fiber from the seed, in that "cotton gin" which is essentially associated with the industrial development of the South. The fiber is baled and sold to the cotton merchants, while the separated seed begins its interesting career. It is shipped to near-by oil mills, where it is carefully stored in dry, cool bins in the "seed house." The first operation is that of screening, performed by a machine of the type shown in Fig. 62. This consists of a large frame box, in the interior of which is a hollow cylinder covered with wire cloth or perforated sheet steel, the openings in which are too small to permit the passage of the seed but sufficiently large to allow foreign materials such as dirt and sand to fall through. From the end of the sand screen the seed drops into a rapidly vibrating shaker, across which it is blown, while any large heavy substances, like nails, stones, etc., drop down through an opening provided for that purpose. One form of shaker or cleaner is shown in

[1] *Cotton Seed Products.* D. Van Nostrand Company.

Fig. 63. A combination reel cleaner and shaker is sometimes used. Magnets are occasionally employed for removing metallic particles.

After cleaning, the seed passes to the linter, which removes the particles of adhering fiber, sometimes amounting to 22 pounds per ton of

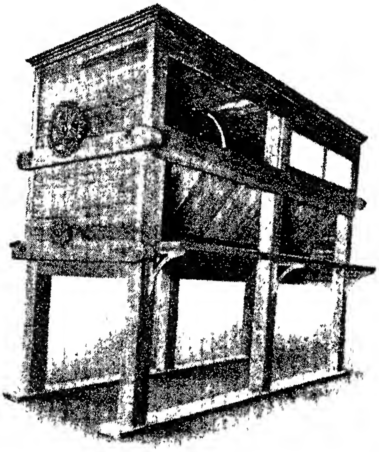


Fig. 62. — Improved Sand and Boll Screen. (W. P. Callahan & Co.)

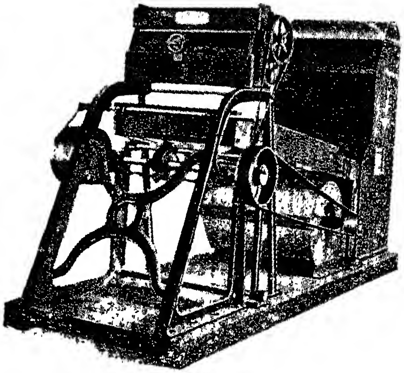


Fig. 63. — Buckeye Cotton-seed Cleaner.

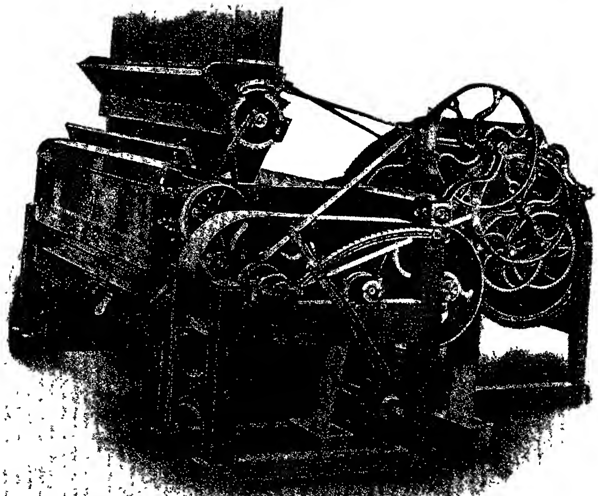


Fig. 64. — Callahan Cotton-seed Linter.

seed, which are sold for cotton batting. The linters (Fig. 64) are simply close cutting gins. The extracted fiber (also called "linters") is delivered to a baling press, while the seed passes to the huller, other-

wise known as the "decorticator," or "sheller." Fig. 61 shows one form of huller (an English machine), containing a revolving disk on which are set a number of radiating knives, which must be constantly kept sharp.

Fig. 65 represents an American huller, containing a rotating cylinder with longitudinal knives. The seeds are cut open by the knives, and pass from the machine as a mixture of hulls and kernels. The two must then be separated by screening. In Fig. 65 the screen is mounted directly under the huller; in other cases it is a separate machine. Cotton seed is occasionally crushed without hulling, or "undecorticated." The cake thus produced is estimated to have only one-fifth the value of cake from hulled seed.

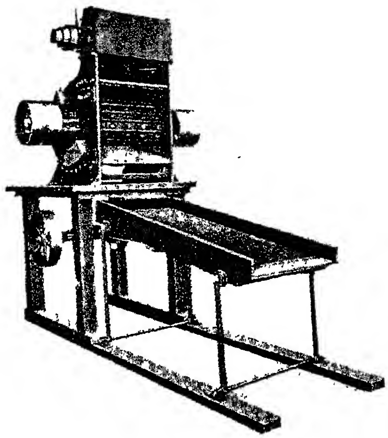


Fig. 65. — Buckeye Huller and Huller Shaker.

The hulls are carried away and sold. They were formerly used as fuel, but at the present time can be sold for feed at a higher price than is represented by their fuel value. The kernels or "meats" must be treated almost immediately after hulling to avoid their spoiling. Ordinarily they pass directly from the huller screen to the crushing rolls. The rolls are similar to those used for linseed, but the feeding arrangement is different. The feed hoppers are usually of iron, with wooden extensions upward to increase the capacity for holding meats. Crushing opens the oil cells of the meats and prepares them for the cooker. The cookers, or heaters, are usually one-high (sometimes two-high), with open tops. The cooked meal is not discharged directly to the former, as in linseed practice, but to a receiving heater, which keeps the meal warm until wanted. Fig. 66 shows a usual arrangement, with the former mounted under the receiving heater. The molding of the cakes and filling of the presses are conducted as in a linseed mill, camel's-hair press cloth being commonly employed. The box type of press is invariably used,[1] with two hydraulic pressures, about the same

[1] Brass boxes are generally preferred to those of steel. They are said to impart a lighter color to the oil.

in intensity as those employed for linseed. The expressed oil is filtered and stored like linseed oil. The cakes are usually ground.

The oil is a staple article of commerce, and is sold under uniform established rules and gradings on the New York Produce Exchange.

The decorticated upland cotton seed yields an odorless, dark brownish-green oil, having a specific gravity varying from 0.92 to 0.93. After being treated with alkaline solutions, a clear, yellow oil, which is odorless and of pleasant taste, is racked off. The residue is suitable for soap stock. The refined oil boils at about 600 degrees F. and

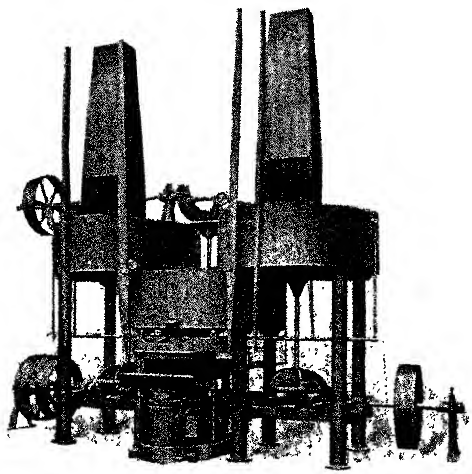


FIG. 66. — CALLAHAN HEATERS FOR COTTON-SEED.

congeals at about 50 degrees for summer-pressed and 32 degrees for winter-pressed oil. American seed yields a clearer oil than the Egyptian or Indian seed, and the upland seed produces a clearer oil than that from the seacoast. The oil made in Great Britain is not as clear as ours, because the seed is mostly Egyptian or Indian, and has not been decorticated. Nine-tenths of the oil annually produced in the United States enters into the composition of food products, principally lard substitutes and salad and cooking oils. The total oil production is steadily increasing, and an increasing amount is being retained for home consumption.

In the process of refining, the impurities in suspension are usually

allowed to settle, and the clear supernatant oil is drawn off. To the latter from 10 to 15 per cent of caustic soda (10 degrees to 28 degrees Baumé), according to the nature of the oil, is added, and the mixture agitated at a temperature of 100 to 110 degrees F. for 45 minutes, the precipitate being allowed to settle from 6 to 36 hours. The residues obtained are disposed of as soap stock, etc. The yellow oil resulting from this process is further purified by being heated and allowed to settle again, or by filtration, and is called summer yellow oil. Winter yellow oil is made from the above material by chilling it until it partially crystallizes, and then separating the stearin formed (about 25 per cent) in presses similar to those used for lard. For the preparation of the white oil of commerce the yellow oil obtained as above is shaken up with 2 to 3 per cent of fuller's earth and filtered.

Cotton oil cake is bright yellow in color, with a sweet, nutty flavor, but it becomes discolored and deteriorates with age. This is also true of the meal. Cotton-seed meal is the richest of all foods in protein, so rich that it is unfit for feeding without modification. The following shows the usual range of composition:

FOOD CONSTITUENTS OF COTTON-SEED MEAL.

Fresh, air-dry material.

	Water.	Ash.	Protein.	Fiber.	Nitrogen-Free Extract.	Fat.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Minimum	5.29	1.72	23.27	1.88	9.13	2.18
Maximum	18.52	10.62	52.88	15.15	38.68	20.66
Average	8.52	7.02	43.26	5.44	22.31	13.45

Cotton-seed meal is extensively used as a fertilizer. Its value for this purpose, based on analysis, is from $20 to $25 per ton. At times the market price is below the technical value. The meal is frequently adulterated with ground hulls. These sometimes give the meal a dark color.

Before the development of the cotton-oil industry an average price for the seed was $6.00 per ton. The present average value is about $16.00 per ton. The annual increase in natural wealth due to this difference is over $50,000,000. There are annually expended $8,000,000

for the transportation of the seed and its products. From one ton of seed there are produced, on the average —

39 gallons of crude oil at 30½ cents		$11.89
780 pounds of meal at $20 per ton		7.30
913 pounds of hulls at $3.50 per ton		1.60
27 pounds of linters at 3 cents		.81
Total		$21.60
Less cost of manufacturing	$ 4.00	
and cost of seed	15.75	19.75
Profit		$1.85

The familiar Grimshaw chart, reproduced as Fig. 68, illustrates the productive possibilities of the seed. This was first published some years ago, when the yield of oil usually obtained was somewhat less than at present.

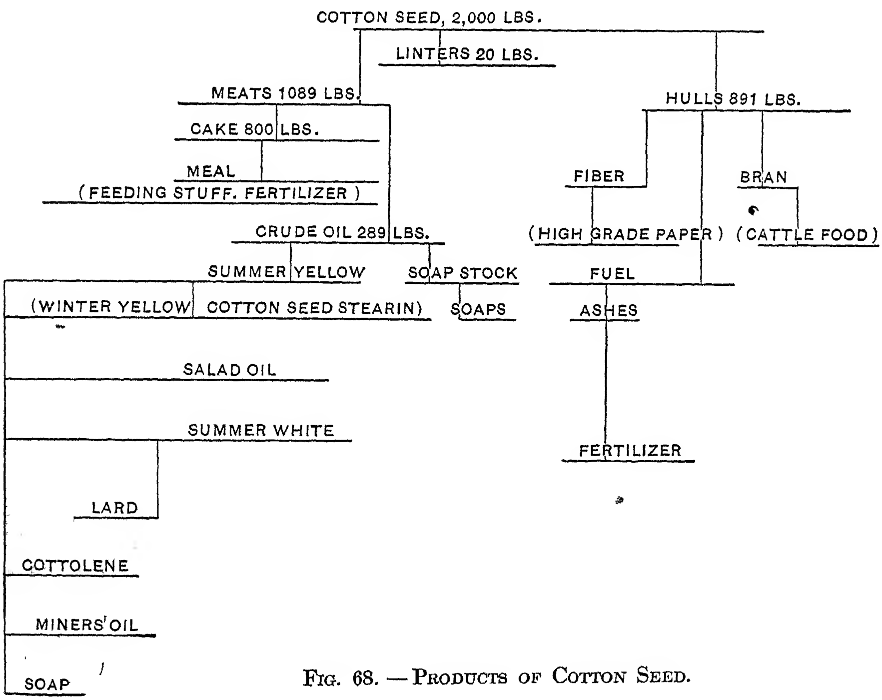


Fig. 68. — Products of Cotton Seed.

Cotton seed is graded as "prime" or "off." Prime seed must be clean, dry, and sound, free from dirt, thresh, and bolls. There is no primary market, and no general established system for inspection and grading. Seed purchase was formerly a matter of private contract

between grower and mill owner, but this condition has been improved by the standard rules governing transactions in cotton seed and its products adopted by the Interstate Cotton Seed Crushers' Association, May 18, 1905. The crop makes very light demand upon the fertility of the soil. No other staple crop is as satisfactory in this respect. When the pressed meal from the seed is returned to the soil by way of the intestinal tract of the grower's live stock, the actual loss per acre for a crop of 300 tons of lint is estimated not to exceed one-half pound of phosphoric acid, $1\frac{3}{4}$ pounds of potash, and $1\frac{1}{4}$ pounds of nitrogen. The refuse after picking cotton amounts to about 850 pounds per acre. This is usually stripped bare by live stock which is turned into the fields after the harvest. A process has been patented, however, for utilizing the stems for the preparation of fiber for cotton bagging. Five tons of stalks are said to produce one ton of bark, yielding 1500 pounds of fiber. The bark of the roots (*gossypii radicis cortex* U. S. P.) contains a medicinal principle similar in its properties to ergot. A crude method of purchasing seed which prevails in some sections consists in exchanging meal for seed at the rate of 800 pounds of meal to one ton of seed. This practically amounts to giving back to the grower the meal produced from his seed; but in most cases he would do better to sell seed and buy meal.

England is the only European country having a considerable industry in cotton-seed products, and its annual production is a small fraction of that of this country, while the combined trade of France and Germany is a similar small fraction of the English trade. Most of the seed is brought to Europe with the lint adhering — a practice which is rendered practicable only by the low cost of water transportation. The seed before delinting, air dried, shows about 10 parts of water, 5 of ash, 20 of protein, 23 of fiber, 20 of fat, and 22 of nitrogen-free extract, in 100. The composition is, however, quite variable.

The hulls of the cotton seed, air dried, show in 100 parts, 11 of water, 3 of ash, 4 of protein, 45 of fiber, 2 of fat, and 36 of nitrogen-free extract. They are a cheap and satisfactory substitute for hay, but are so bulky as to require excessive storage room. They are liable to heat if kept in bulk. The ashes of the hulls are of especial value for fertilizing soils for growing tobacco, their average composition in per cent being, water 9, phosphoric acid 9, potash 23, lime 9, magnesia 10, and carbonic acid 11.

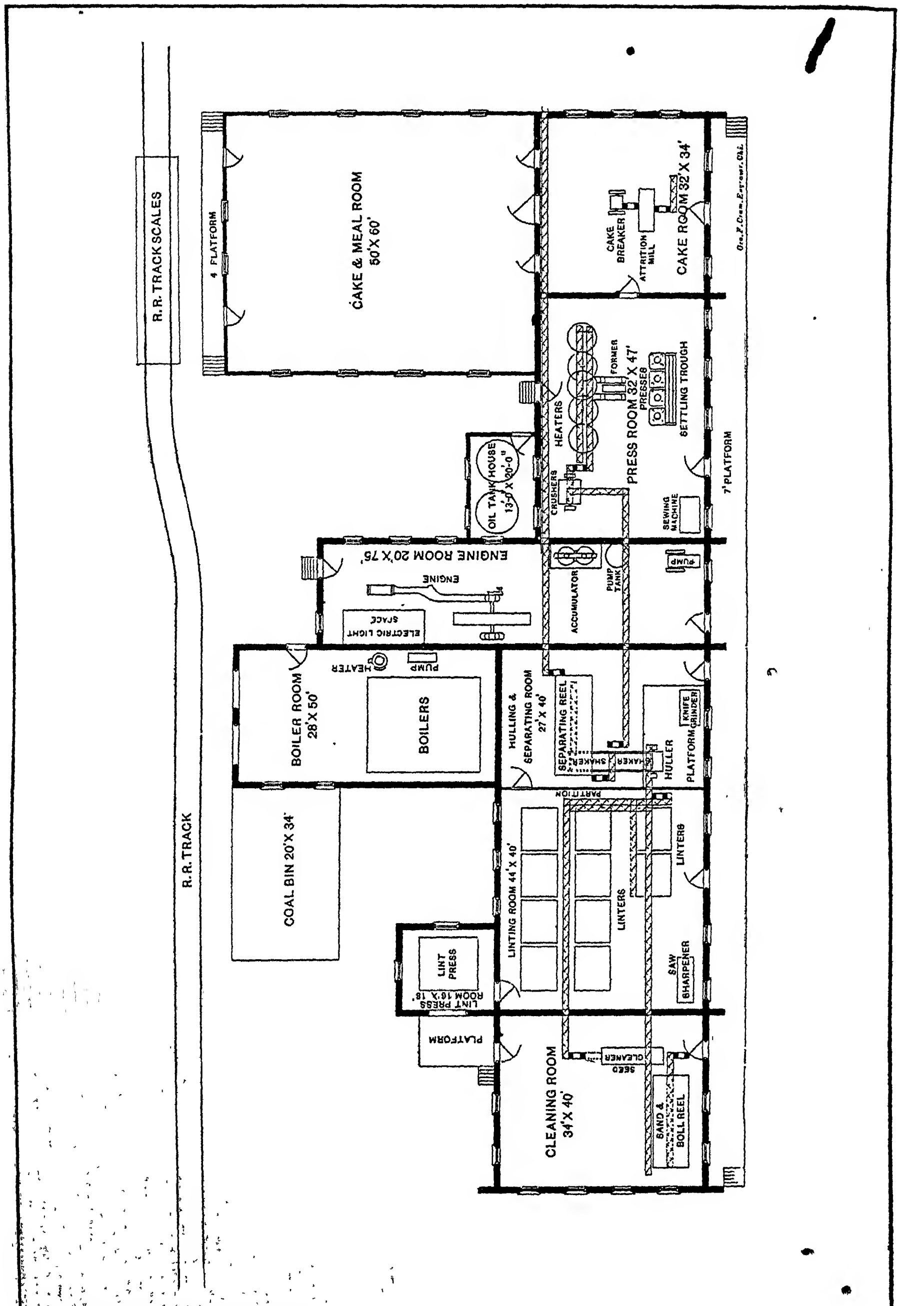


Fig. 71. — 80-Ton Cotton-seed Oil Mill. (Buckeye Iron and Brass Works.)

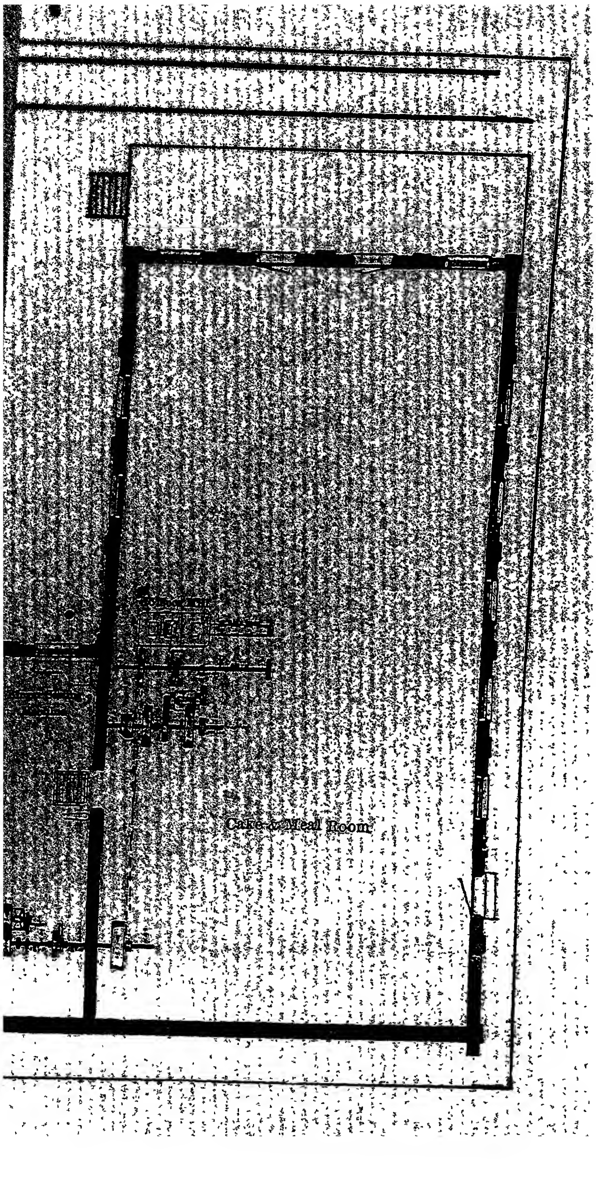

Cake & Meal Room

Fig. 70 represents a cotton seed oil mill of 60 tons daily capacity. Fig. 71 shows a plan for a well-arranged 80-ton mill.[1] The seed enters at the lower left-hand corner, passes through the sand and boll reel and seed cleaner, and is then carried to the linters. The location of the grinding machine for the linter saws is indicated, as is that of the lint press, or baling press for the linters. The seed is next delivered to the pulling and separating room, from which the meats are carried (through the intervening hydraulic department) to the rolls, heaters, former, and presses. The sewing machine for press cloths is located in the press room. Oil from the settling troughs passes to the oil-tank house, while the cakes from the presses go to the cake breaker and attrition mill. No refining is done. The buildings are one story, with a high basement for shafting.

[1] The cotton oil mills are generally of moderate capacity — sixty tons being the most common size. This is equivalent to the average 12-press linseed mill.

APPENDIX

TABLE I.

COST PER GALLON OF OIL F.O.B. MILLS, BASED ON YIELDS OF 19 POUNDS OF OIL AND 37 POUNDS OF CAKE PER BUSHEL.

Cost of Seed at Mill plus Working Cost per Bushel.	Value of Cake per Ton of 2000 Pounds F.O.B. Mill.				
	$17.	$18.	$19.	$20.	$21.
$1.16	$.3338	$.3265	$.3193	$.3119	$.3045
1.17	.3378	.3305	.3232	.3158	.3084
1.18	.3417	.3344	.3272	.3198	.3124
1.19	.3457	.3384	.3311	.3237	.3163
1.20	.3496	.3423	.3351	.3277	.3203
1.21	.3536	.3463	.3390	.3316	.3242
1.22	.3575	.3502	.3430	.3356	.3282
1.23	.3615	.3542	.3469	.3395	.3321
1.24	.3654	.3581	.3509	.3435	.3361
1.25	.3694	.3621	.3548	.3474	.3401
1.26	.3733	.3660	.3588	.3514	.3440
1.27	.3773	.3700	.3627	.3553	.3480
1.28	.3812	.3739	.3667	.3593	.3519
1.29	.3852	.3779	.3706	.3632	.3559
1.30	.3891	.3818	.3746	.3672	.3598
1.31	.3931	.3858	.3785	.3711	.3638
1.32	.3970	.3897	.3825	.3751	.3677
1.33	.4010	.3937	.3864	.3790	.3717
1.34	.4049	.3976	.3904	.3830	.3756
1.35	.4088	.4016	.3943	.3869	.3795
1.36	.4128	.4055	.3983	.3909	.3835
1.37	.4167	.4094	.4022	.3948	.3874
1.38	.4207	.4134	.4062	.3988	.3914
1.39	.4246	.4173	.4101	.4027	.3953
1.40	.4286	.4213	.4141	.4067	.3993
1.41	.4325	.4252	.4180	.4106	.4032
1.42	.4365	.4292	.4220	.4146	.4072
1.43	.4404	.4331	.4259	.4185	.4111
1.44	.4444	.4371	.4298	.4224	.4151
1.45	.4483	.4410	.4337	.4263	.4190
1.46	.4523	.4450	.4377	.4303	.4230
1.47	.4562	.4489	.4416	.4342	.4269
1.48	.4602	.4529	.4456	.4382	.4309
1.49	.4641	.4568	.4495	.4421	.4348
1.50	.4681	.4608	.4535	.4461	.4388

TABLE I — *Continued.*

COST PER GALLON OF OIL F.O.B. MILLS, BASED ON YIELDS OF 19 POUNDS OF OIL AND 37 POUNDS OF CAKE PER BUSHEL.

Cost of Seed at Mill plus Working Cost per Bushel.	Value of Cake per Ton of 2000 Pounds F.O.B. Mill.				
	$17.	$18.	$19.	$20.	$21.
$1.51	$.4720	$.4647	$.4574	$.4500	$.4427
1.52	.4760	.4687	.4614	.4540	.4467
1.53	.4799	.4726	.4653	.4579	.4506
1.54	.4839	.4766	.4693	.4619	.4546
1.55	.4878	.4805	.4732	.4658	.4585
1.56	.4918	.4845	.4772	.4698	.4625
1.57	.4957	.4884	.4811	.4537	.4664
1.58	.4997	.4924	.4851	.4777	.4704
1.59	.5036	.4963	.4890	.4816	.4743
1.60	.5076	.5003	.4930	.4856	.4783
1.61	.5115	.5042	.4969	.4895	.4822
1.62	.5155	.5082	.5009	.4935	.4862
1.63	.5194	.5121	.5048	.4974	.4901
1.64	.5234	.5161	.5078	.5014	.4941
1.65	.5273	.5200	.5127	.5053	.4980
1.66	.5312	.5240	.5167	.5093	.5019
1.67	.5352	.5279	.5206	.5132	.5059
1.68	.5391	.5319	.5246	.5172	.5098
1.69	.5431	.5358	.5285	.5211	.5138
1.70	.5470	.5398	.5325	.5251	.5177
1.71	.5510	.5437	.5364	.5290	.5217
1.72	.5549	.5472	.5404	.5329	.5256
1.73	.5589	.5516	.5443	.5369	.5296
1.74	.5628	.5555	.5482	.5408	.5335
1.75	.5667	.5594	.5521	.5447	.5374
1.76	.5707	.5634	.5561	.5487	.5414
1.77	.5746	.5673	.5600	.5526	.5453
1.78	.5786	.5713	.5640	.5566	.5493
1.79	.5825	.5752	.5679	.5605	.5532
1.80	.5865	.5792	.5719	.5645	.5572
1.81	.5905	.5831	.5758	.5684	.5611
1.82	.5944	.5870	.5798	.5724	.5651
1.83	.5983	.5909	.5837	.5763	.5690
1.84	.6022	.5948	.5877	.5803	.5730
1.85	.6061	.5987	.5916	.5842	.5769

TABLE I — *Continued.*

COST PER GALLON OF OIL F.O.B. MILLS, BASED ON YIELDS OF 19 POUNDS OF OIL AND 37 POUNDS OF CAKE PER BUSHEL.

Cost of Seed At Mill plus Working Cost per Bushel.	Value of Cake per Ton of 2000 Pounds F.O.B. Mill.			
	$22.	$23.	$24.	$25.
$1.16	$.2972	$.2900	$.2827	$.2753
1.17	.3012	.2939	.2866	.2792
1.18	.3051	.2979	.2906	.2832
1.19	.3091	.3018	.2945	.2871
1.20	.3130	.3058	.2985	.2911
1.21	.3170	.3097	.3024	.2950
1.22	.3209	.3137	.3064	.2990
1.23	.3249	.3176	.3103	.3029
1.24	.3288	.3216	.3143	.3069
1.25	.3328	.3255	.3182	.3109
1.26	.3367	.3295	.3222	.3148
1.27	.3407	.3334	.3261	.3188
1.28	.3446	.3374	.3301	.3227
1.29	.3486	.3413	.3340	.3267
1.30	.3525	.3453	.3380	.3306
1.31	.3565	.3492	.3419	.3346
1.32	.3604	.3532	.3459	.3385
1.33	.3644	.3571	.3498	.3425
1.34	.3683	.3611	.3538	.3464
1.35	.3722	.3650	.3577	.3503
1.36	.3762	.3690	.3616	.3543
1.37	.3801	.3730	.3656	.3582
1.38	.3841	.3770	.3696	.3622
1.39	.3880	.3809	.3735	.3661
1.40	.3920	.3849	.3775	.3701
1.41	.3959	.3887	.3815	.3740
1.42	.3999	.3927	.3855	.3780
1.43	.4038	.3966	.3894	.3819
1.44	.4078	.4005	.3933	.3859
1.45	.4117	.4044	.3972	.3898
1.46	.4157	.4084	.4011	.3928
1.47	.4196	.4123	.4050	.3977
1.48	.4236	.4163	.4090	.4017
1.49	.4275	.4202	.4129	.4056
1.50	.4315	.4242	.4169	.4096

TABLE I — *Concluded.*

COST PER GALLON OF OIL F.O.B. MILLS, BASED ON YIELDS OF 19 POUNDS OF OIL AND 37 POUNDS OF CAKE PER BUSHEL.

Cost of Seed at Mill plus Working Cost per Bushel.	Value of Cake per Ton of 2000 Pounds F.O.B. Mill.			
	$22.	$23.	$24.	$25.
$1.51	$.4354	$.4281	$.4209	$.4135
1.52	.4394	.4321	.4249	.4175
1.53	4433	.4360	.4288	.4214
1.54	.4473	.4400	.4328	.4254
1.55	.4512	.4459	.4366	.4253
1.56	.4552	.4479	.4406	.4333
1.57	.4591	4518	.4445	.4372
1.58	.4631	.4558	.4485	.4412
1.59	.4670	.4597	.4524	.4451
1.60	.4710	.4637	4564	.4491
1.61	.4749	.4676	.4603	.4530
1.62	.4789	.4716	.4643	.4570
1.63	.4828	.4755	.4682	.4609
1.64	.4868	.4795	.4722	.4649
1.65	.4907	.4834	.4761	.4688
1.66	.4947	.4874	.4801	4727
1.67	.4986	.4913	.4840	.4767
1.68	.5026	.4953	.4880	.4806
1.69	.5065	.4992	.4919	.4846
1.70	.5105	.5032	.4959	.4885
1.71	.5144	.5071	.4998	.4925
1.72	.5184	.5111	.5037	.4964
1.73	.5223	.5150	.5077	.5004
1.74	.5262	.5189	.5116	.5043
1.75	.5301	.5228	.5155	.5082
1.76	.5341	.5268	.5195	.5122
1.77	.5380	.5307	.5234	.5161
1.78	.5420	.5347	.5274	.5201
1.79	.5459	.5386	.5313	.5240
1.80	.5499	.5426	.5353	.5280
1.81	.5538	.5465	.5392	.5319
1.82	.5578	.5505	.5432	.5359
1.83	.5617	.5544	.5471	.5398
1.84	.5657	.5584	.5511	.5438
1.85	.5696	.5623	.5550	.5477

GLOSSARY

BULK OIL. Oil in tank cars or in the crusher's tanks.

CAKE. The compressed seed meal left after the extracting of the oil.

CAKE TEST. The percentage of oil in the cake.

CANDLING. The operation of inspecting the rolls to ascertain whether they are in true cylindrical shape; performed by looking along the line of contact toward a candle held behind the stand.

CHANGES. Same as *Pressings*.

CLOTH. (1) Filter cloth, used for clarifying oil in the filter press; (2) Press cloth, used for wrapping the meal cake.

COLD PRESSED. Linseed oil from unheated seed meal.

COOKER. Same as *Kettle*.

COOKING. Same as *Tempering*.

CRUDE. Cotton-seed oil direct from the presses.

CRUSHING. Manufacturing linseed oil.

DECORTICATE. To separate the hulls and meats of seed.

DELINT. To remove lint from cotton seed.

DOCKAGE. Same as *Screenings*.

FLUID. The liquid used in the hydraulic operative system.

FOOTS. Matter in suspension or solution in linseed oil.

FORMER. The machine in which the seed meal is compacted preliminary to placing it in the press.

GALLONAGE. Capacity in gallons.

GIN. The machine which separates cotton seed from the fiber.

GROSS BUSHEL. Fifty-six pounds of nominal flax seed, consisting of both the pure seed and the screenings.

HIGH. Refers to the number of rolls in a stand; thus 3-*high* means a stand containing three rolls.

HULL. The shell encasing the meat of a seed.

HULLER. Same as *Sheller*.

IMPURITY. Same as *Screenings*.

KETTLE. The heater in which the seed meal is heated, moistened, and agitated.

LEG. A grain elevator, including belt, buckets, boot, and housing.

LINSEED. Flax seed.

LINT. The short fiber adhering to cotton seed after ginning.

LINTER. (1) The machine which removes the short lint from the cotton seed. (2) (plural) the product thus removed.

LIVER. To become of a "cheesy" structure, as when pigment and oil are imperfectly blended in a mixed paint.

MAT. The woven-hair covering usually used on the plates of the hydraulic press.

MEAL. Roughly applied to ground flax seed, either before or after tempering; also to ground cake. Properly speaking, *ground seed* is fed from the rolls to heaters; *seed meal* is delivered from the heaters; and *oil meal* is produced by grinding cake.

MEAT. The hulled kernel of a seed.

MOLDER. (1) Same as *Former*. (2) The workman who operates the former.

MULLER. One of the large grinding stones formerly used to crush seed.

NET BUSHEL. Fifty-six pounds of pure flax seed.

NITROGEN-FREE EXTRACT. Carbohydrates, or the heating elements in feeding stuffs, not including the fibrous elements.

OFF. Cotton seed or cotton oil of inferior grade.

OIL CAKE. Same as *Cake*.

OIL MEAL. See *Meal*.

OUTPUT. The daily capacity of a mill, expressed in bushels.

PAN. Used for carrying the cake from the former to the press.

PARCEL. Any quantity of linseed oil constituting one sale or shipment.

PIGMENT. A solid white or coloring material incorporated in a paint.

PLATE. (1) The unit of division in a filter press. (2) The flat metal piece between each two cakes in the hydraulic press.

PRIME. The best grade of cotton seed or of cotton-seed oil.

PRESSING. The charging of a press with meal cakes.

PRESSMAN. The workman who delivers the cake to the press.

PRODUCTION. The amount of product obtained per bushel of seed crushed, in pounds.

RAW. A term applied to oil which has not been chemically or mechanically treated after its expression, otherwise than by filtration.

SCREENINGS. Any impurity contained in flax seed.

SECOND-HAND. Oil sold the second time, but not in the ordinary course of distribution from the crusher to a small consumer.

SEED. Flax seed.

SHAKER. The screen used for cleaning seed.

SHELLER. The machine which separates seeds from their hulls.

SHRINKAGE. The difference in weight between the seed and the oil and cake therefrom.

SOAKAGE. The absorption of oil by a barrel.

SPOT. Cash or immediate delivery, i.e., "spot" seed is seed for immediate delivery; "future" seed being for delivery two, three, or four months hence, as the case may be.

STAND. A series of cylindrical rolls placed vertically, for crushing seed.

STRIP. To remove the press cloth from the cake.

STRIPPER. (1) The man who strips the cake. (2) A machine for stripping the cake.

SUMMER. Summer-pressed oil, cotton-seed oil having a high freezing point.

SWEEP. The revolving arm inside the heater.

SWEETMEATS. Concentrated oil, prepared by gradually heating.

TACKY. A rubber-like condition of paint or sweetmeats, in which the drying is imperfect and the coat lacks hardness.

TANKAGE. (1) The storage capacity of the mill. (2) Foots. (Rare.)

TEMPERING. The operation performed in the heater.

TEST. (1) The percentage of impurities in the seed. (2) See *Cake test*.

TONNAGE. The daily capacity of a cotton-seed-oil mill, expressed in tons of seed crushed.

TOWER. In a grain elevator, the elevator proper, exclusive of horizontal conveyors and storage tanks.

TRIMMER. A machine for trimming the edges from cake; also the man who operates the machine.

TRIMMING. (1) Cleaning up seed from the hold of a vessel after the grain will no longer run of itself to the boot. (2) Removing the soft edges of the cake.
TRIMMINGS. The trimmed-off portions of an oil cake.
UNDECORTICATED. Not hulled.
WINTER. Winter-pressed oil, cotton-seed oil having a low freezing point.
WORKING NET. A method of hedging against shrinkage involving the assumption that the "test" of the seed is equal to the percentage of shrinkage.
YIELD. The number of pounds of oil produced from one bushel of seed.

INDEX

INDEX.